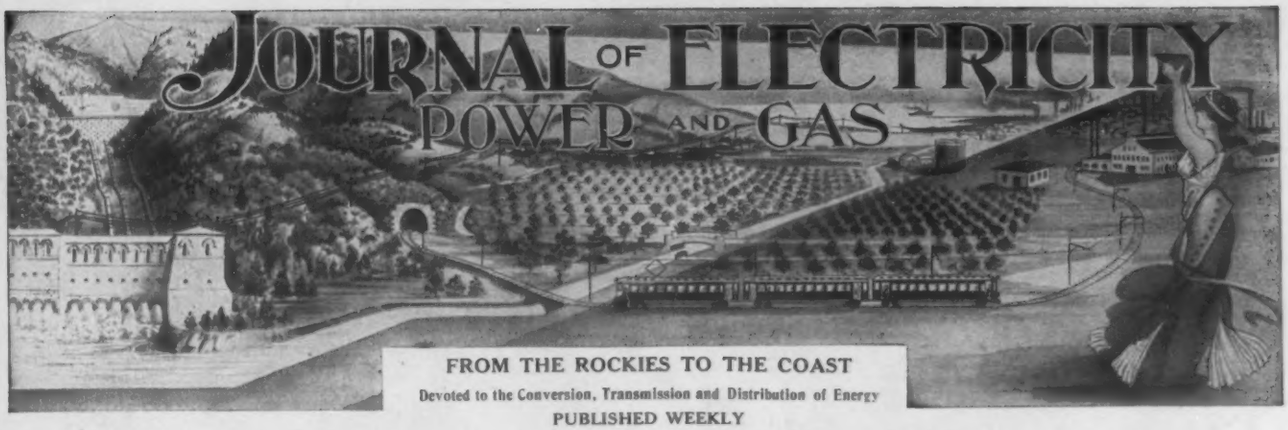
JOURNAL OF ELECTRICITY
POWER AND GAS
FROM THE ROCKIES TO THE COAST
Devoted to the Conversion, Transmission and Distribution of Energy
PUBLISHED WEEKLY

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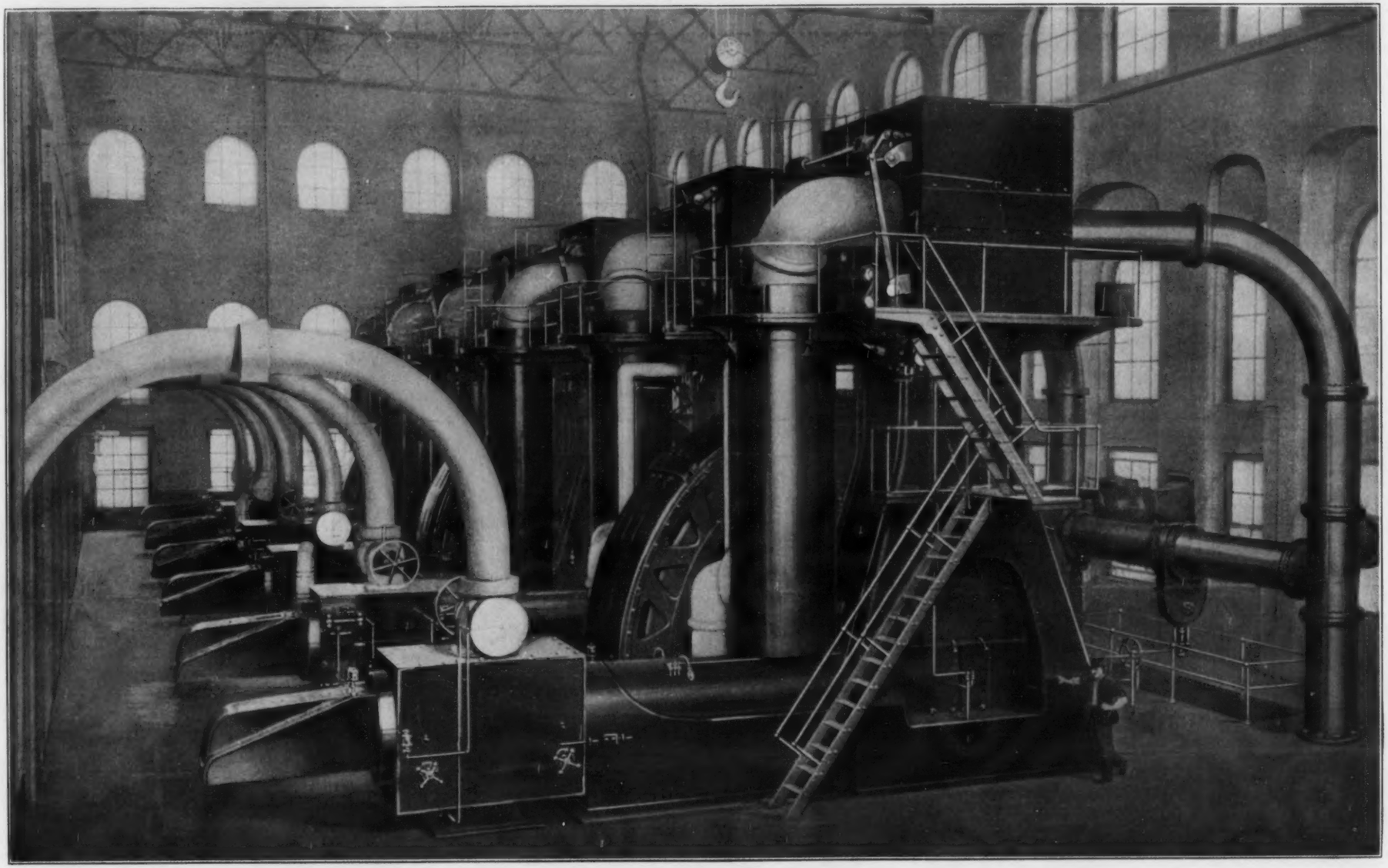


View of Engine Room from Northwest Corner

THE
Journal of Electricity, Power and Gas
Devoted to the Conversion, Transmission and Distribution of Energy.

VOLUME XXI. SAN FRANCISCO, CAL., AUGUST 22, 1908 No. 8

A Modern Steam Power Central Station

ONE of the most striking examples of recent steam power plant design is the plant of the Pacific Light & Power Co., operating at Redondo, California. The most radical departure from recent Eastern central station practice lies in the adoption, as prime movers, of one of the most modern types of reciprocating engines in lieu of steam turbines.

Considerably at variance with the customary method of procedure with large plants, the Purchasers, desiring to secure the most modern and economical steam power plant possible, entrusted the design of this station to a firm of Contracting Engineers with whom was placed a fixed sum contract for the entire installation.

As customary guarantees for water consumption of prime movers, efficiencies of boilers and various auxiliaries, under ideal conditions, were considered of no protection under commercial conditions of variable load, a definite complete plant economy was guaranteed, based on commercial railway load, subject to penalty and bonus stipulations.

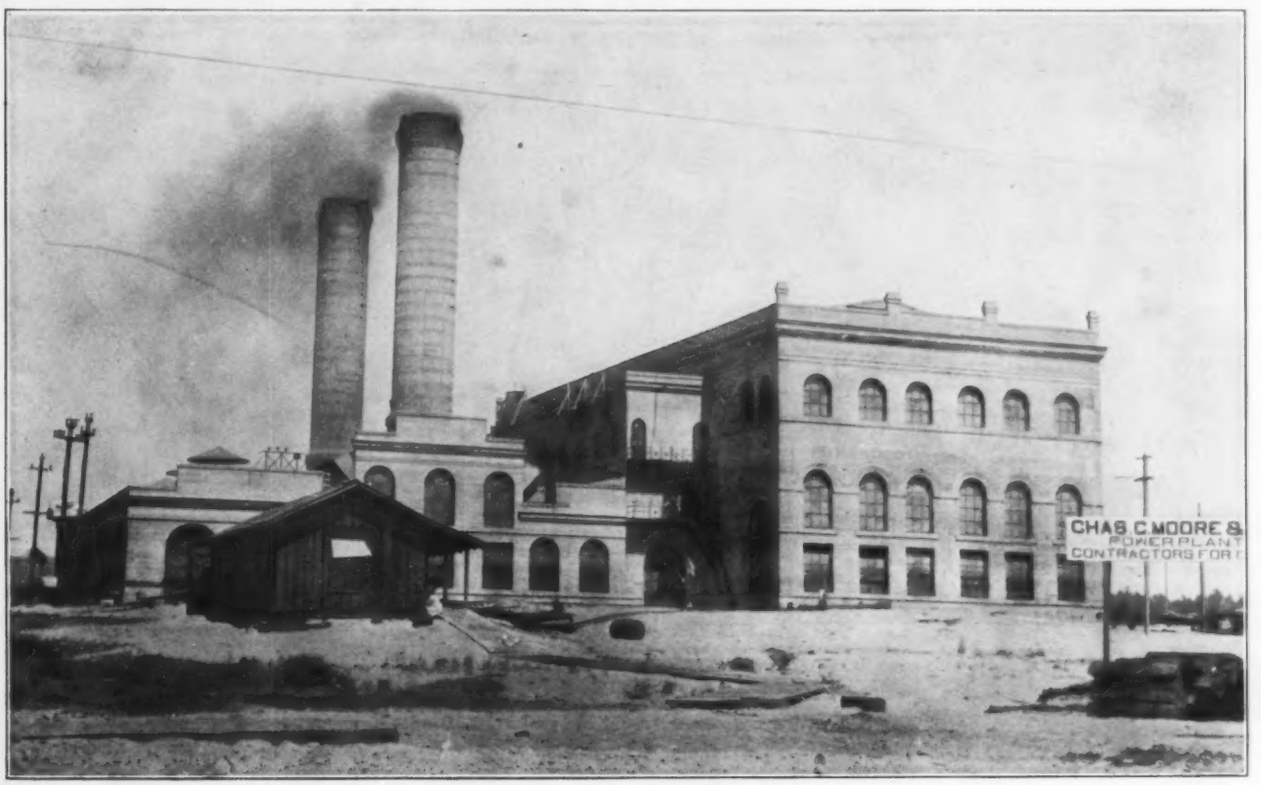
A further feature of interest was the provision of the contract that the plant be started and operated by the contractor for a period of at least three months previous to the economy test, also during test, thus thoroughly organizing the operating crew and perfecting the adjustment of the apparatus.

The test to determine the economy of the plant was to have been of ninety days duration on one unit operating on commercial railway load. Inasmuch as the plant had been operating regularly over six months previous to test, it was considered that the endurance run was an unnecessary feature of test, and the test period was therefore reduced from ninety to fifteen days.

As a result of undoubtedly the most elaborate power plant test ever undertaken, the Committee in charge have reported an actual economy under commercial load, which has not only earned for the contractors the largest amount of money ever paid as a bonus on a steam power plant guarantee, but has also exceeded the economy of any central station of published record.

The contract for this station was placed with Chas. C. Moore & Co. Engineers, of San Francisco, California, the plant having a nominal capacity of 15,000 K.W., there being three units of 5,000 K.W. each; the contract covered the entire plant installation, including machinery foundations excepting only switchboard, building, circulating water pipe line, wharf and any other work outside of the building.

In order to obtain an ample supply of water for condensing purposes, the plant was located at Redondo, a beach town eighteen miles southwest of Los Angeles.



View of Building from the West

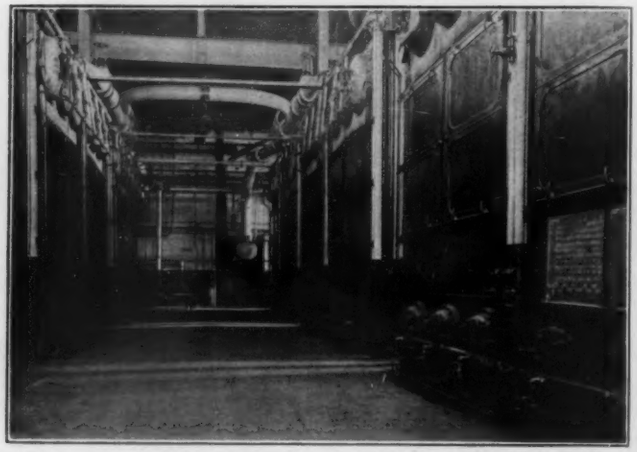
Eighteen thousand volts were determined as ample for this distance of transmission, the alternators being wound for this potential without the use of step-up transformers.

The Pacific Light & Power Company is engaged in both lighting and power business, although the greater part of the current from this station is used for operating the railways of Los Angeles and suburban towns, including all of the well known Huntington system of inter-urban railroads.

An interesting feature of this station is its successful parallel operation with other water and steam power plants, be-

longing to the extensive holdings of the Pacific Light & Power Co.

The fuel situation is ideal. Crude oil is obtained from wells near the plant, in which the power company is largely interested. Owing to the system of oil firing in use, the boiler room labor cost is at a minimum. Consideration of these facts in connection with the remarkable economy attained warrants the statement that this plant is developing steam power



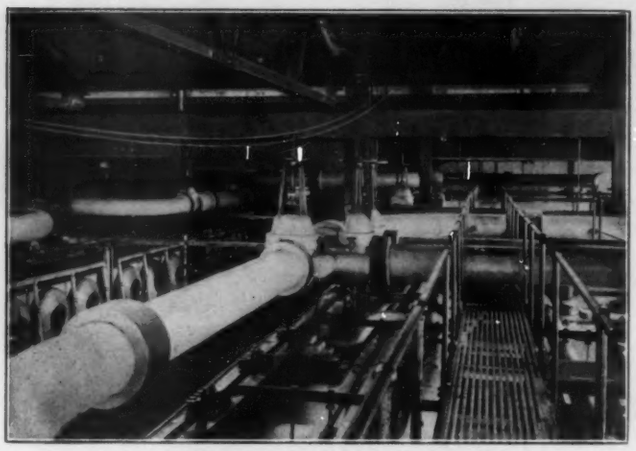
Firing Alley Between Second and Third Units

at a cost probably lower than that of any other large American Central Station.

While this station is a record breaker for economy, the designers maintain that had fuel cost been of greater consideration, even greater efficiency could have been attained, as a number of minor points of economy were sacrificed in favor of simplicity of design and operation.

The panel system of design was followed, as will be noted from the accompanying drawings. Owing to the fact that each main engine consists in reality of two compound engines connected to the one shaft, each having an independent steam and exhaust connection, a further subdivision has been possible with each unit in the connection of one-half of the panel of boilers to each high pressure cylinder,

GENERAL ARRANGEMENT.



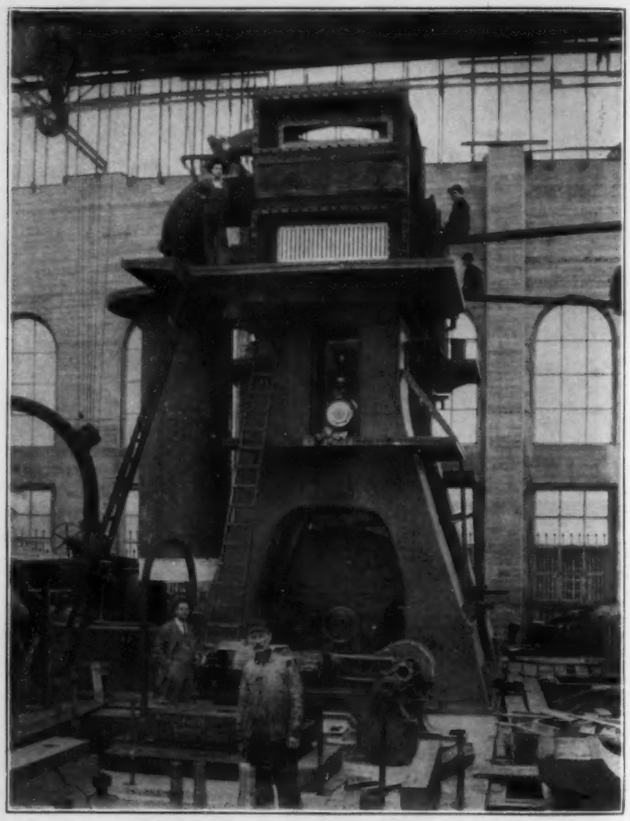
Pipe Platforms on Tops of Boilers

and the provision of a separate condenser and air pump for each low pressure cylinder, giving in effect the freedom from breakdown corresponding to six instead of three plant units.

All auxiliaries, excepting air pumps, are steam driven, operating non-condensing, the exhaust steam being utilized in feed water heaters.

The air pumps for each unit are motor driven, power being furnished from the main generator, insuring gradual starting of both air pumps in synchronism with main engine.

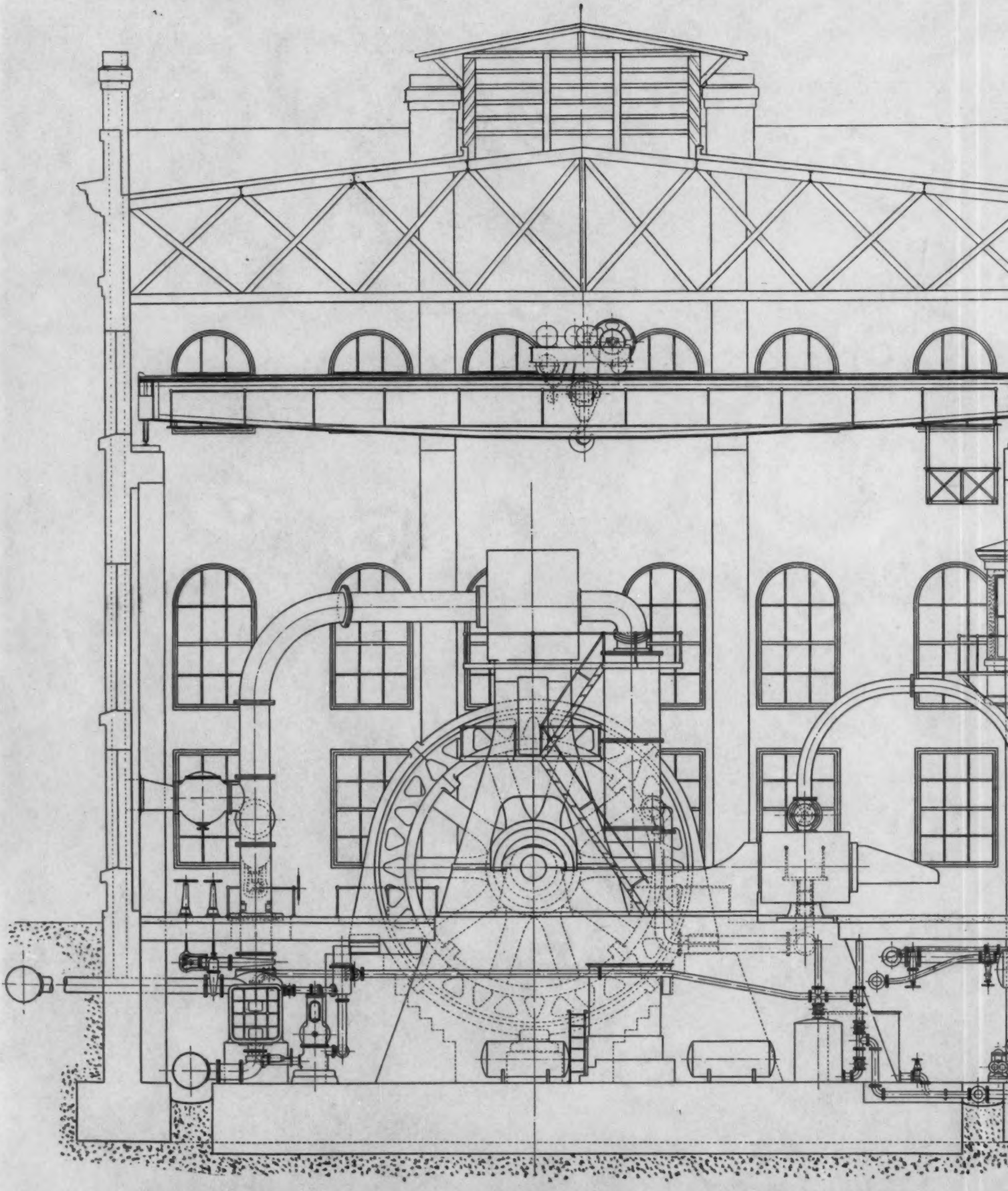
The adoption of a syphon system of suction and discharge pipes for circulating water, is due to location of plant, the use of conduit or canal system being impossible. There are two 50″ suction mains and one discharge line of same size and these are supported on a pile wharf carried out to deep water at low tide. The suction pipes are primed by means of a large motor driven vacuum pump operating through a stand pipe, which prevents carrying of water into vacuum pump cylinders. When once started suction is maintained by three engine driven centrifugal circulating pumps, located in pump pit, there being one pump for each unit. Each pump has separate connections to both suction lines. All pumps discharge into a com-

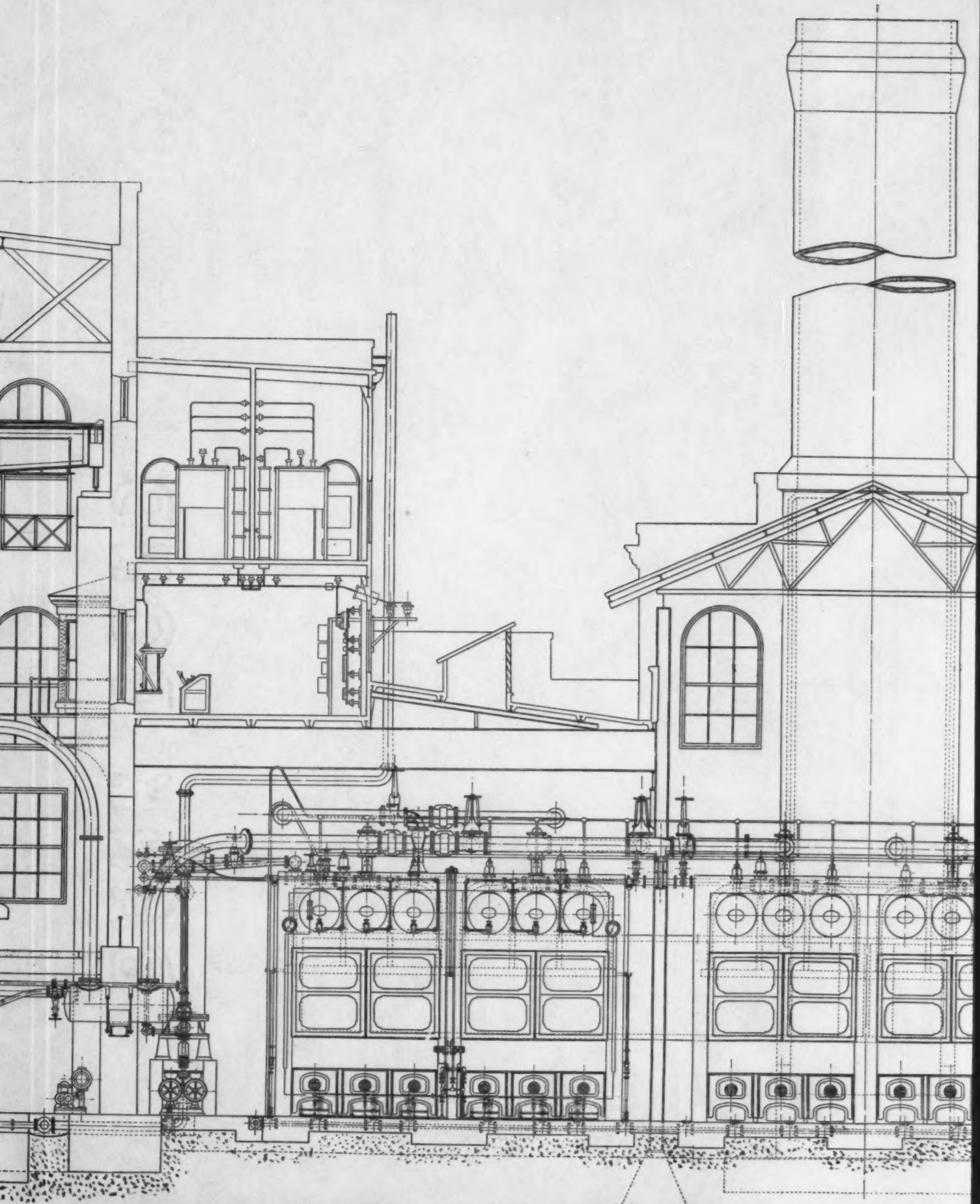


McIntosh & Seymour Engine in Course of Erection Showing Vertical Low Pressure Cylinder

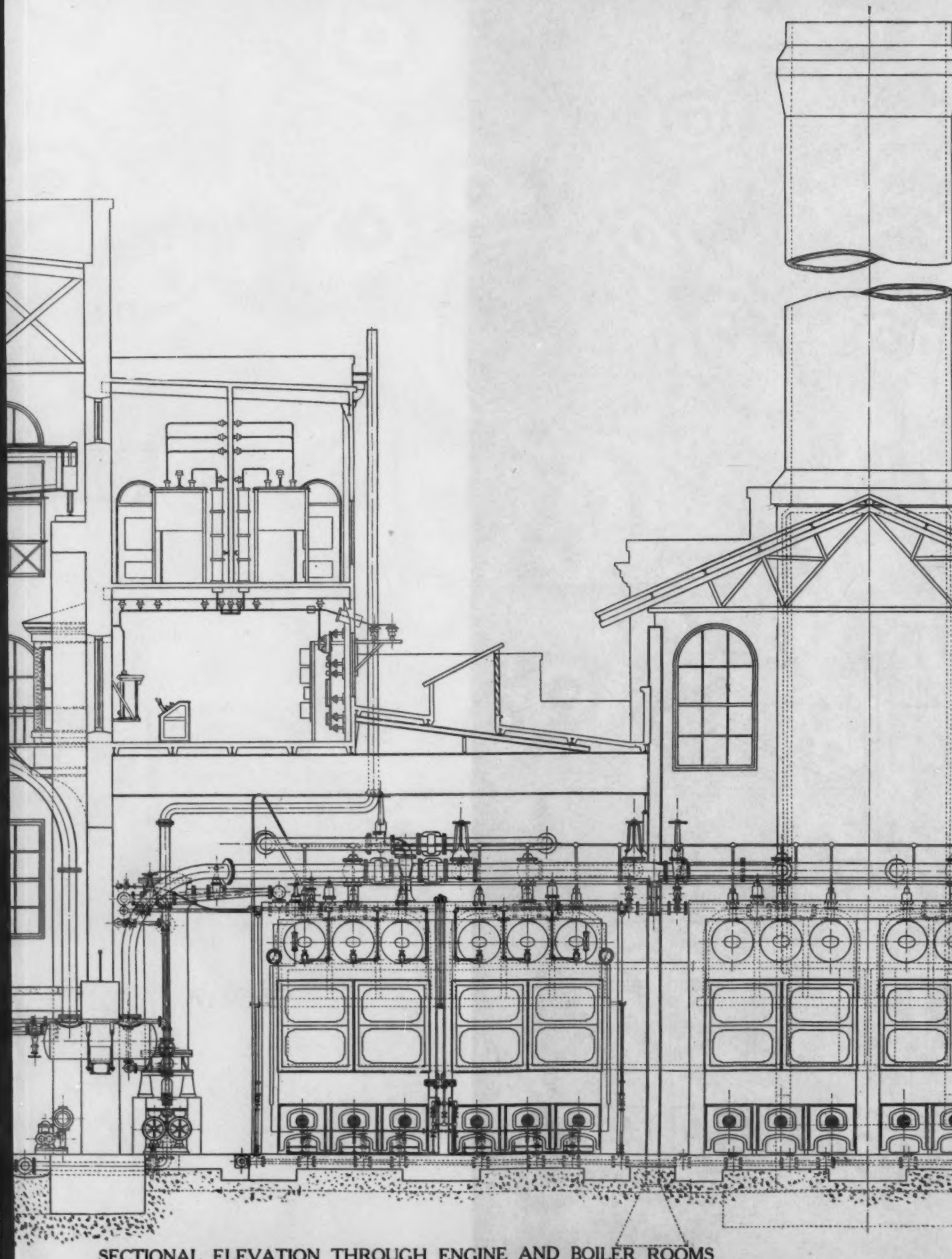
mon supply main having inlet connections to all condensers. All condenser outlets are connected to the one return main. The flexibility of this system of condensers is at once apparent. Any pump may be used to supply any set of condensers; although when two or more pumps are running their operation is necessarily in parallel. The regulation of relative amounts of water through various condensers is accomplished by the condenser discharge valves; the pumps are speeded up or down, and the number of pumps in service is increased or decreased as load conditions require.

The provision of two condensers on each unit, with cross connected exhaust, is a marked feature of this installation. Should it become necessary for one condenser to be cut out of service, the exhaust steam from both low pressure cylinders may be led to the remaining condenser, making operation non-condensing unnecessary, except for a failure of circulating water or the breakdown of both condensers at one time. Actual operation shows but slight falling off in vacuum due to this doubling of load on one condenser. Eliminating air leaks in exhaust pipes and minimizing the loss of vacuum due

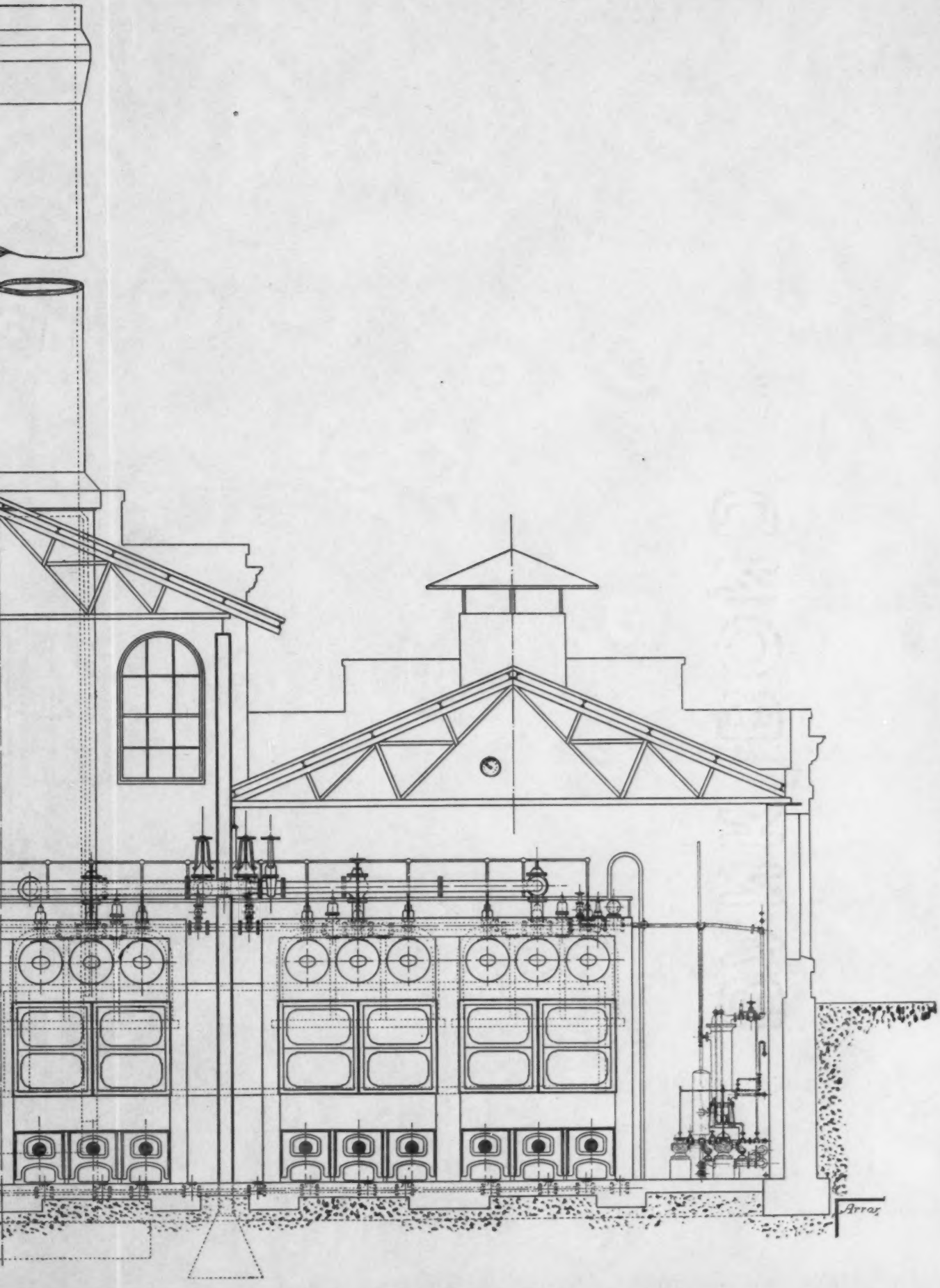




SECTIONAL ELEVATION THROUGH ENGINE AND BOILER ROOMS



SECTIONAL ELEVATION THROUGH ENGINE AND BOILER ROOMS

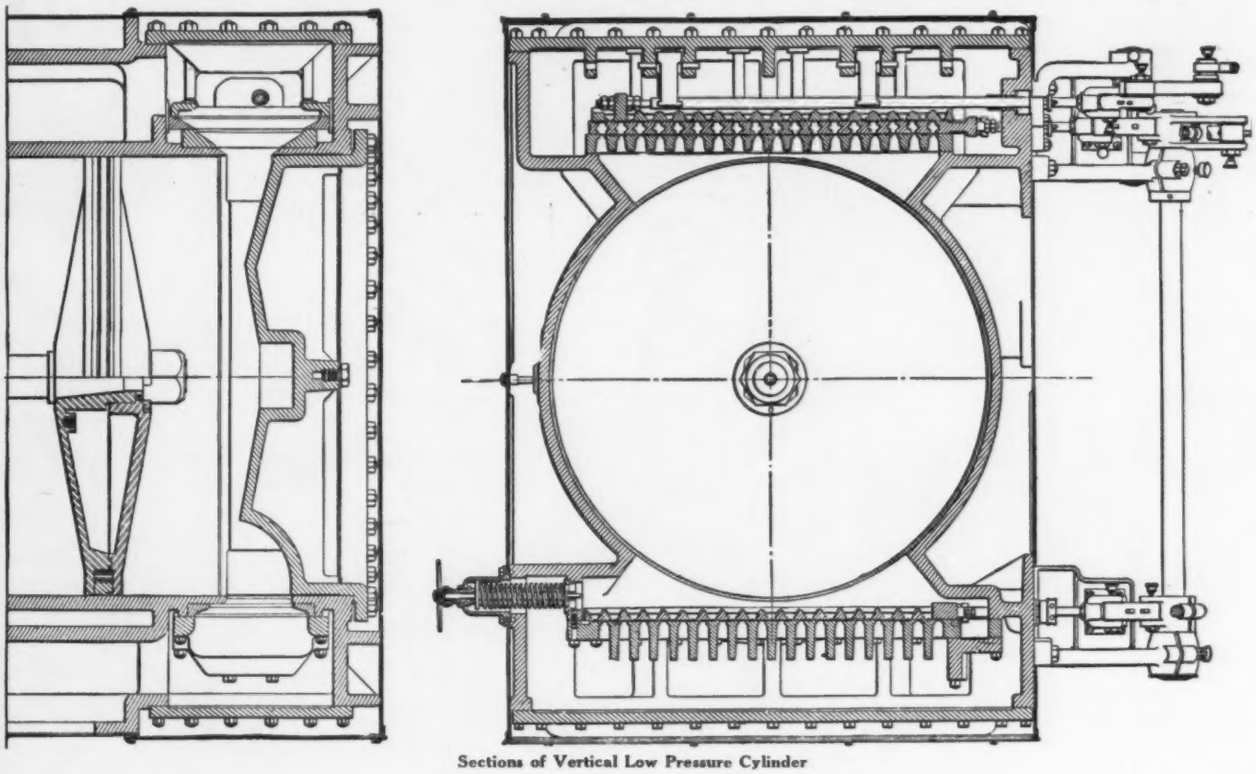

Arraz

to pipe turns has been given very careful consideration in all its details, the vacuum joints being as carefully made as in high pressure steam piping. In regular operation with ample water at 70 deg. F., vacuum from 28" to 28.5" is easily maintained.

Each condenser is provided with an Edwards triplex suction valveless air pump, motor driven.

on nominal load, the sixth being for reserve. The waste gases from boilers discharge through short re-inforced concrete flues to centrally situated re-inforced concrete chimneys.

A novel feature of the boiler plant is the use of secondary tight fitting sliding dampers, which are completely closed during standby period, to cut down fuel loss due to circulation of



Sections of Vertical Low Pressure Cylinder

Each air pump discharges into a vertical stand pipe to eliminate entrained air, after which the water, subsequently used as boiler feed, is passed through a Volz heater, being in effect a primary heater in the upper portion of condenser shell. The feed water is thus heated by the exhaust steam entering condenser materially increasing the plant economy.

The feed is next passed through a Marine type feed water filter, in order to remove any excessive quantity of cylinder oil, after which it enters the suction main and is pumped into boilers, passing through auxiliary heaters enroute. The successful treatment of feed water containing quantities of cylinder oil seems to have been successfully accomplished only on the Pacific Coast. In this station or in others the complete separation is not attempted, but the plant is regularly operating, reasonable care being exercised in feeding oil to main engines, with such degree of separation as to place the plant on a practicable operating basis. Entrained oil in exhaust from auxiliaries is so completely removed by means of Cochrane Exhaust Oil Separators that this condensed steam, drained from the body of closed Goubert heaters, is as clear as drinking water, and is used for feed purposes.

All boilers are fitted with superheaters, designed for approximately 100 deg. F. superheat at boiler nozzles, giving from 80 deg. to 90 deg. at main engine throttles. Working steam pressure is 175 lbs. maintained at engine throttle. All auxiliary engines operate on same steam pressure and superheat as main engines with no difficulties due to valves, wear, etc.

There are six Babcock & Wilcox Boilers in each panel corresponding to each main engine, five boilers being operated cold air through boiler setting.

Boilers are fitted with Peabody Oil Furnaces, burners firing forward from bridgewall as shown on drawing. Fuel oil is supplied to burners by steam driven pumps. The system of storage and handling of fuel oil being more fully described below. For each panel there is one large Snow Feed Pump, having compound steam end; a fourth pump answers as reserve for the entire plant.

As is common with all McIntosh & Seymour engines, a superheating receiver is placed between each set of high and low pressure cylinders, superheated steam being supplied to the heating coils at boiler pressure. The condensation from these coils is almost as hot as the water within the boilers, and the proper disposition of this hot water materially affects the economy of the plant. Each unit is provided with one Snow receiver pump, enabling the return of this hot feed direct to boilers. Each McIntosh & Seymour engine is controlled by a shaft governor, operating the auxiliary cut-off valves, on admission to both high pressure and low pressure cylinders. Large counter-balances are provided on engine shafts, insuring smooth running under all conditions.

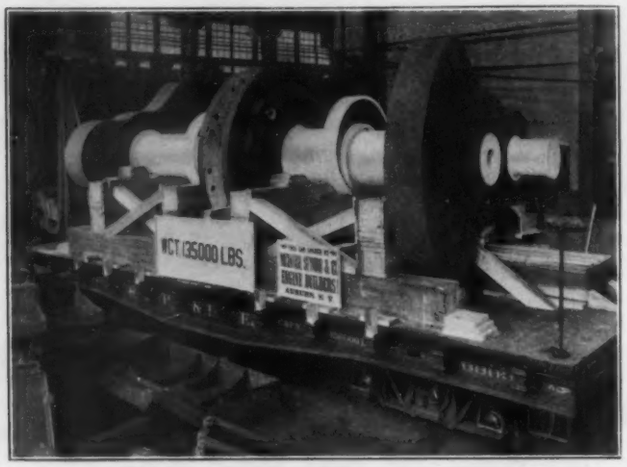
Previous to acceptance of plant, an actual demonstration was made, showing that unit could be successfully run with one, two, three or four cylinders; also with one end of any cylinder out of commission. As one cylinder of the unit is at worst liable to injury at one time, the period of shutdown is at most practically limited to that necessary to disconnect one rod.

The plant is complete with minor auxiliaries for convenience in handling and filtering oil, circulating and cooling

water for main engine guides and bearings, facilities for boiler cleaning, feed water purifying and also salt water fire protection.

The main apparatus in detail is described as follows:

BABCOCK & WILCOX BOILERS: There are eighteen Babcock & Wilcox Patent Safety Water Tube Boilers of Forged Steel Construction, arranged in nine batteries of two each. Each boiler consists of twenty-one sections, each having fourteen 4" tubes 18 ft. long, over which there are mounted three steam and water drums 42" diameter. The total effective water heating



McIntosh & Seymour Engine Shaft Ready for Shipping

surface per boiler is 6042 sq. ft. Boilers are designed for 200 lbs. working steam pressure, and in other respects the boilers are in accordance with the standard of the Babcock & Wilcox Co.

SUPERHEATERS: Each boiler is equipped with one Babcock & Wilcox forged steel superheater, designed to give approximately 100 deg. F. superheat at the boiler nozzle. This superheat can be slightly increased or decreased at will by the arrangement of baffling over the first pass.

FURNACES: Each boiler is provided with a Peabody Patent Fuel Oil Burning Furnace. This furnace affords the most efficient boiler performance with crude oil. The furnace is fired from the bridge wall forward, but is controlled at the boiler front. It offers a large volume diverging in the direction of the flame. A large surface of brickwork is exposed, insuring complete combustion. The distribution of flame is over a large area of boiler heating surface, preventing localization of heat and blow-pipe action, and minimizing the possibility of burning out tubes. The furnaces are arranged for the use of three burners per boiler.

McINTOSH & SEYMOUR ENGINES: The plant includes three 34x70x56 combined double horizontal and vertical, compound, side crank, McIntosh & Seymour automatic grid-iron valve engines, each directly connected to one General Electric 5000 K. W., 50 cycle fly-wheel-type alternator, speed 100 r. p. m. Each engine has two horizontal high pressure cylinders and two vertical low pressure cylinders, designed to operate with 175 maintained throttle pressure, 100 deg. F. superheat. The engine governor, which is of the well known McIntosh & Seymour type, is designed to go into the fly-wheel generator.

The valve gear is also of the well known McIntosh & Seymour type, having grid-iron valves. The admission and exhaust valves for all cylinders are operated by means of fixed eccentrics. The point of cut-off in each cylinder is controlled by an auxiliary valve actuated by the one engine governor.

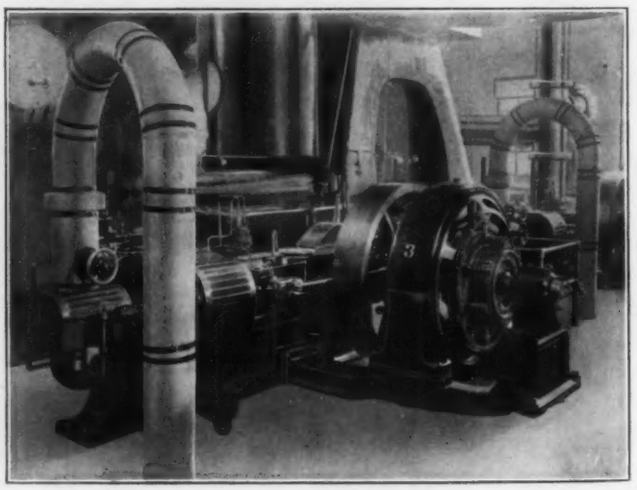
Each engine is fitted with McIntosh & Seymour patented compound delaying dash-pots for parallel operation. They control the governor weights for a small fraction of a second, preventing oscillation of two or more units becoming amplified and from destroying parallel operation of alternators.

Each engine is also fitted with one McIntosh & Seymour electrically operated speed changing mechanism which is situated in the governor, and is operated by a small induction motor, and is controlled from the switch board gallery. This arrangement not only allows the engine while running to be speeded up or down four or five revolutions to bring two or more engines into synchronism, but is also used to divide the load between engines.

Engines are fitted with metallic packing on all piston rods and on all valve rods. The packings on low pressure cylinders are designed to minimize the leakage of air into the low pressure cylinder which tends to destroy vacuum in the condensers. Engine cylinders are lubricated by suitably designed force feed cylinder lubricators.

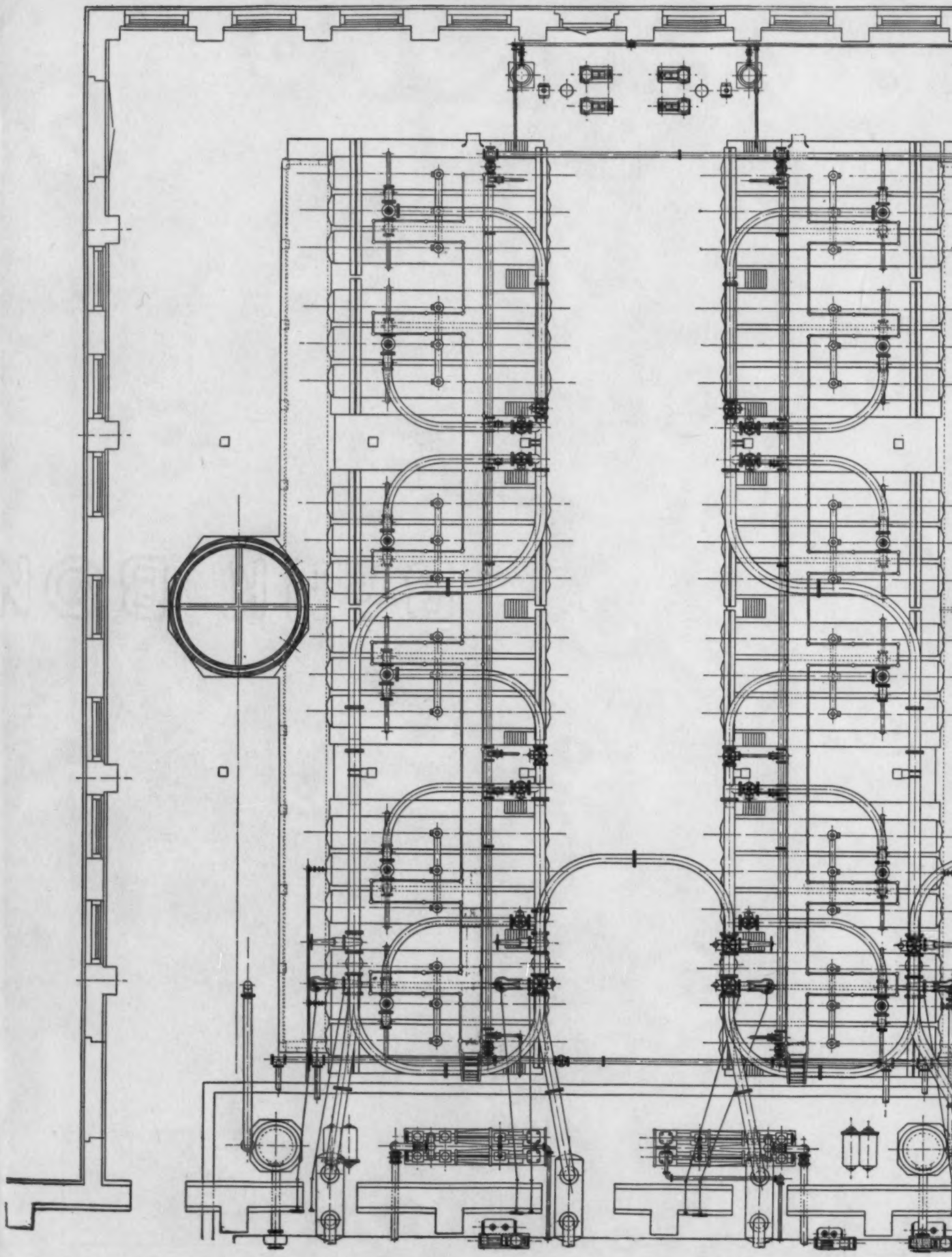
EXCITERS: Situated beside each main engine is one 75 K.W. General Electric Exciter direct connected to one 9x17x12 Harrisburg tandem-compound non-condensing piston valve side crank automatic enclosed self oiling horizontal engine. These engines are designed for the same pressure and superheat as the main engines and operate very satisfactorily under this condition of service.

WHEELER SURFACE CONDENSERS: The plant contains six Wheeler "Admiralty" surface condensers, one being for direct connection to each low pressure cylinder of each main engine. Each condenser contains 5200 sq. ft. of cooling surface. Tubes are brass ¾" O. D. No. 18 B. W. G. In addition to the regular cooling surface of each condenser, there is provided in the upper

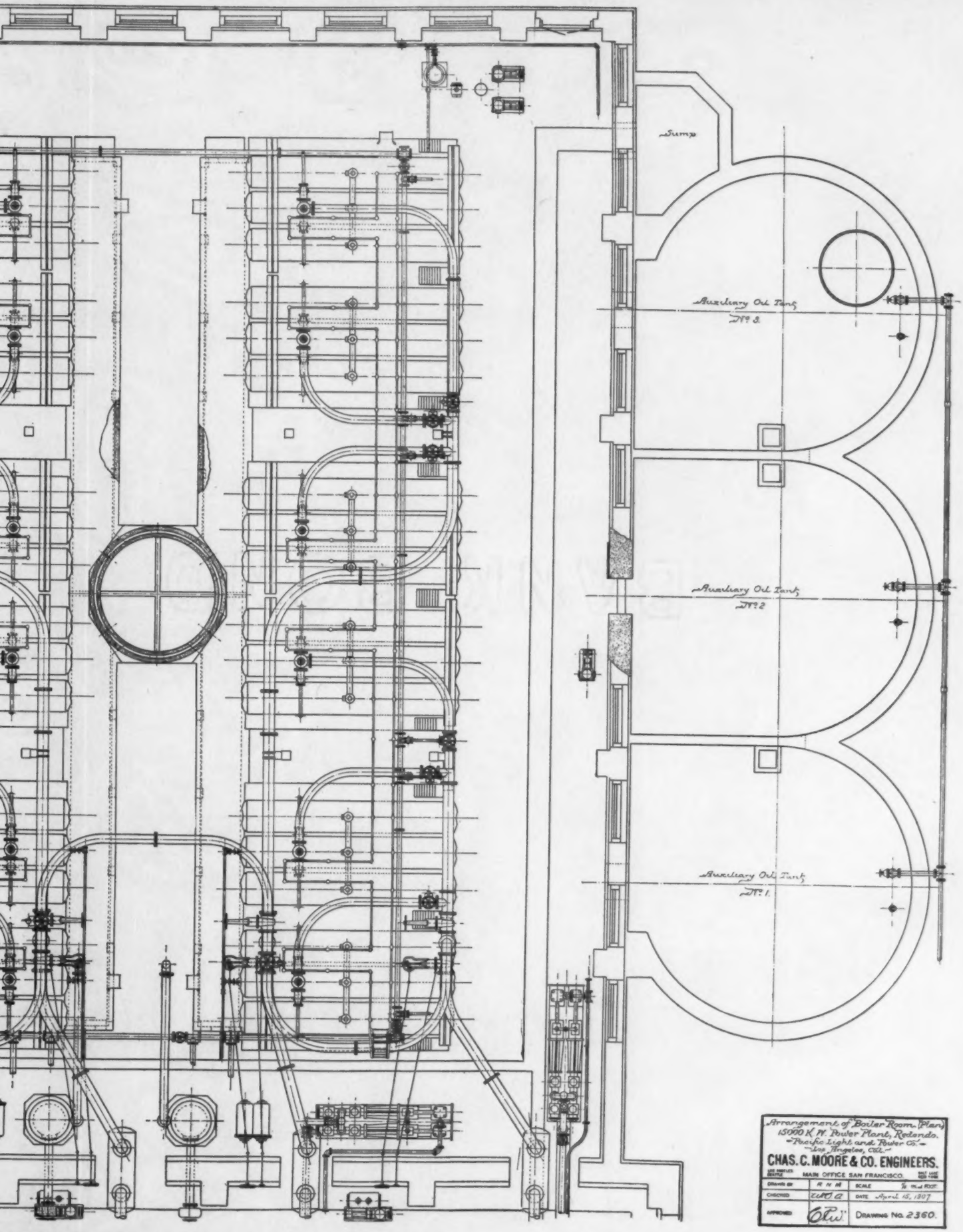


No. 3 Harrisburg Exciter Engine

compartment a series of tubes comprising what is termed the "Volz Heater." After being discharged from the air pump the condensed water passes through this Volz Heater under atmospheric pressure and is heated to within a few degrees of the temperature of the exhaust steam surrounding the heater tubes. The make-up water is also brought in at this point, securing the benefit of heat which would otherwise be wasted.



PLAN OF BOIL



Arrangement of Boiler Room. Plan
15000 K.W. Power Plant, Redondo.
Pacific Light and Power Co.
Los Angeles, Cal.

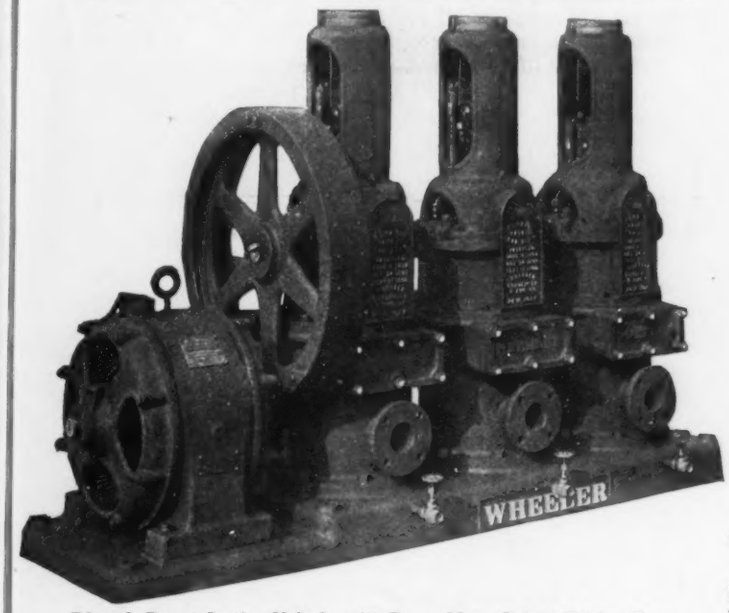
CHAS. C. MOORE & CO. ENGINEERS.
LOS ANGELES SEATTLE — MAIN OFFICE SAN FRANCISCO. — SALT LAKE CITY

DRAWN BY	H N M	SCALE	1/8 INCH = 1 FOOT
CHECKED	C.A.M. C.	DATE	April 15, 1907
APPROVED	C.A.M.	DRAWING No.	2360.

OF BOILER ROOM

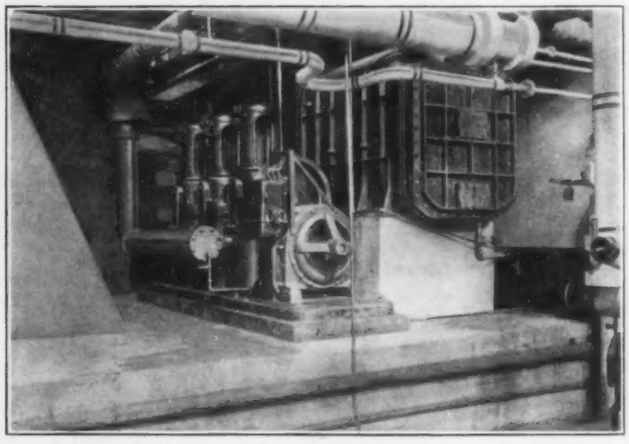
There is furnished in connection with each condenser one Edwards vertical triplex air pump, having three cylinders 16" in diameter, 10" stroke, single acting. This air pump is of the suction valveless type, all suction valves being dispensed with. The condensed steam and non-condensible vapors flow continuously by gravity from the condenser to the base of the pump and are removed by a conical bucket or piston

EDWARDS AIR PUMPS



Edwards Patent Suction Valveless Air Pump, Motor Driven Triplex Type

which works in a base of similar shape. By the action of the bucket, the water is projected without shock at a high velocity through the ports which are cast in the sides of the working barrel. The rising water is followed by a rising bucket, closing the ports and forcing the water and air through the discharge valves of the pump. Each pump is driven by a 25 H.P. General Electric induction motor mounted on an extended base and connected to the pump by a rawhide pinion.



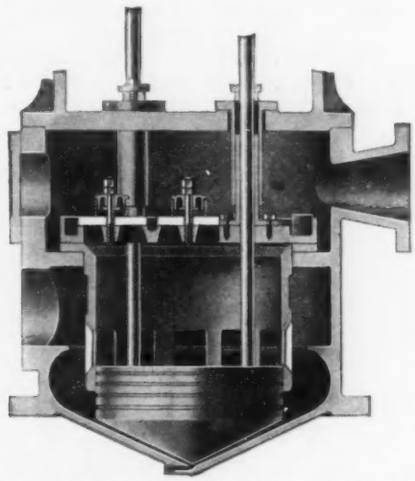
Edwards Triplex Motor Driven Air Pump and Wheeler Condenser

Only one-fifth of the rated power of this motor is required during nominal conditions of load.

There are furnished three engine driven centrifugal circulating pumps, having 20" diameter of discharge and two 15" suctions. Centrifugal pumps are of the double suction type, specially designed for high efficiency service. Each pump is provided with an outboard bearing of the ring-oiling type, the pump and bearing of which are mounted on an extension of the entire base.

CIRCULATING WATER PUMPS:

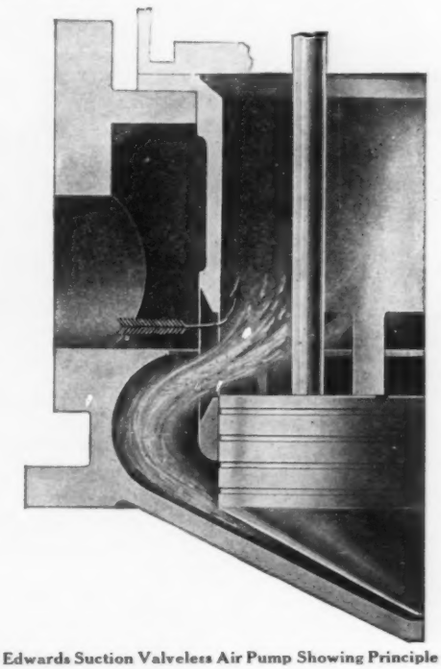
Direct connected to each pump there is a 9x17½x12 Harrisburg tandem compound non-condensing piston valve engine. The limiting speed of this engine is controlled by a throttling governor. An adjustable eccentric enables the economical adjustment of the point of cut-off in the engine.



Section of Edwards Suction Valveless Air Pump

There are four Snow duplex horizontal boiler feed pumps, having compound steam ends, outside center packed water ends. Each pump is of ample capacity for one unit, the fourth pump being for reserve. The pumps operate non-condensing, the exhaust steam being led to the feed water heaters.

BOILER FEED PUMPS:



Section of Edwards Suction Valveless Air Pump Showing Principle of Operation

There are three Goubert vertical auxiliary feed water heaters of the multiple flow type. Each heater contains 1,000 sq. ft. of effective tube heating surface. The supply of exhaust steam is such that under practically all conditions of load, all of the exhaust from the auxiliaries is utilized within these heaters.

GOUBERT AUXILIARY FEED WATER HEATERS:

FUEL OIL PLANT: Fuel oil is stored in large steel tanks having a storage capacity of from 30 to 45 days. The oil is pumped into auxiliary tanks outside of building at one end of the boiler room, each tank having a capacity of 1000 barrels. The top of the auxiliary tanks is on the same level as the boiler room floor line to conform to the Underwriters' requirements. The grade line is about 14 ft. above the floor of tanks, and the surrounding earth is withheld by means of circular retaining walls. These tank pits are roofed over, properly ventilated. All pipes connecting to tanks, have valves located on the boiler room side, there being a 3 ft. concrete wall between the tank compartments and the operator. There are fire partitions between adjacent tanks and fire proof doors connecting. The manhole covers in each tank are padlocked, so that it is impossible for an operator to set fire to any of the tanks as finally designed, although a fire did occur before these precautions were finally adopted.

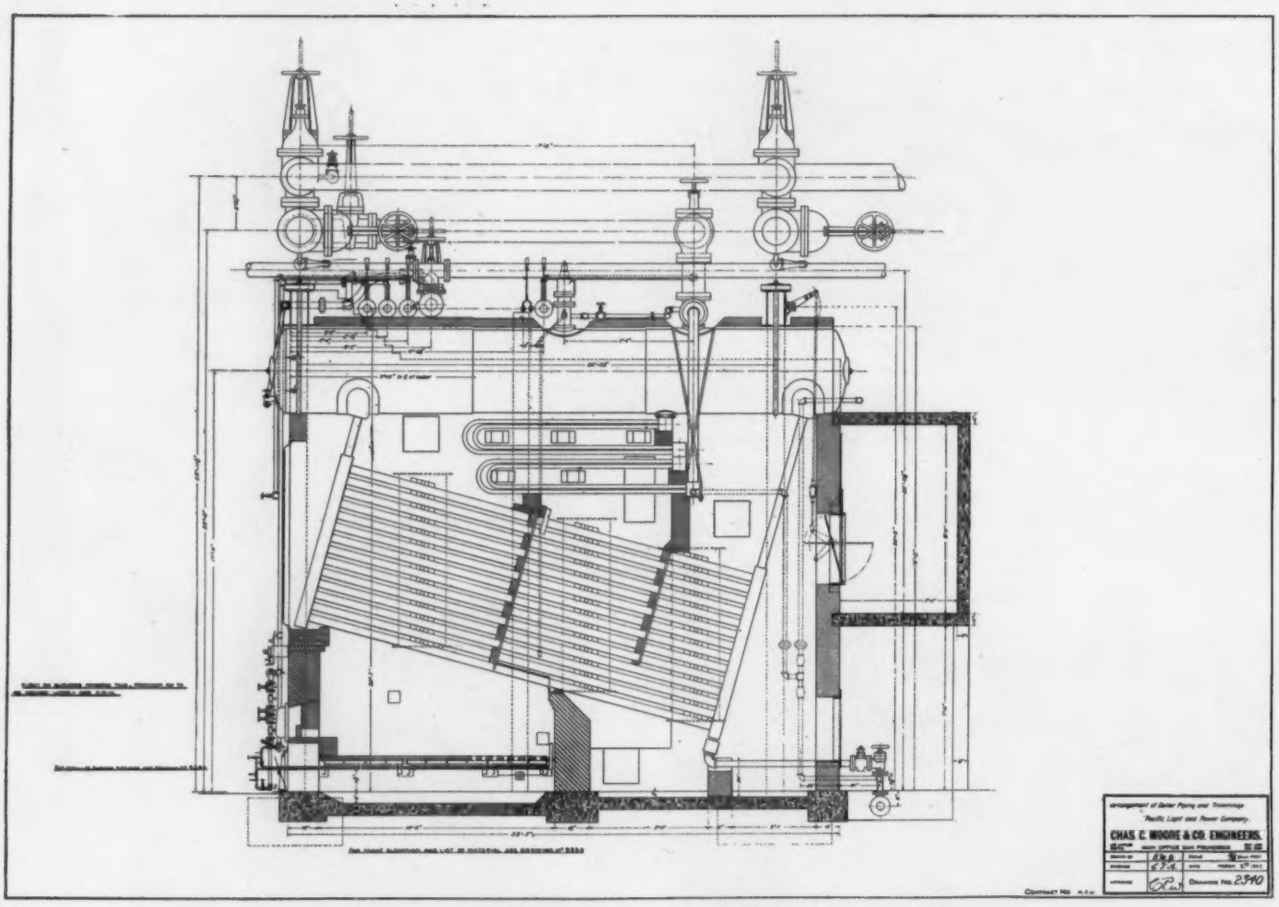
In lieu of steam smothering pipes leading to the interior of the tank compartment, there is placed above each tank, a steam ring of 4" pipe, having an ample number of jets to provide a sheet of steam which would effectually cut off any supply of air from the outside, and promptly smother a fire which might be started by any possible means. This fuel oil installation includes features of design for fire protective purposes which are believed to be the most modern yet adopted.

As originally laid out there was provided a duplicate set of oil feed pumps for each unit, or six oil pumps in all. The plant is so far operated in this way, although it is now being remodelled to have one set of pumps to supply the entire station, requiring but one pump operator instead of three on each shift.

An automatic system of regulation is employed, invented by J. R. Atchison and C. R. Weymouth, the patents for which are controlled by Chas. C. Moore & Co. Engineers.

The oil is pumped under pressures varying from 10 to 50 lbs., depending on load conditions, there being a uniform oil pressure throughout all portions of the plant, all burners being wide open or nearly so.

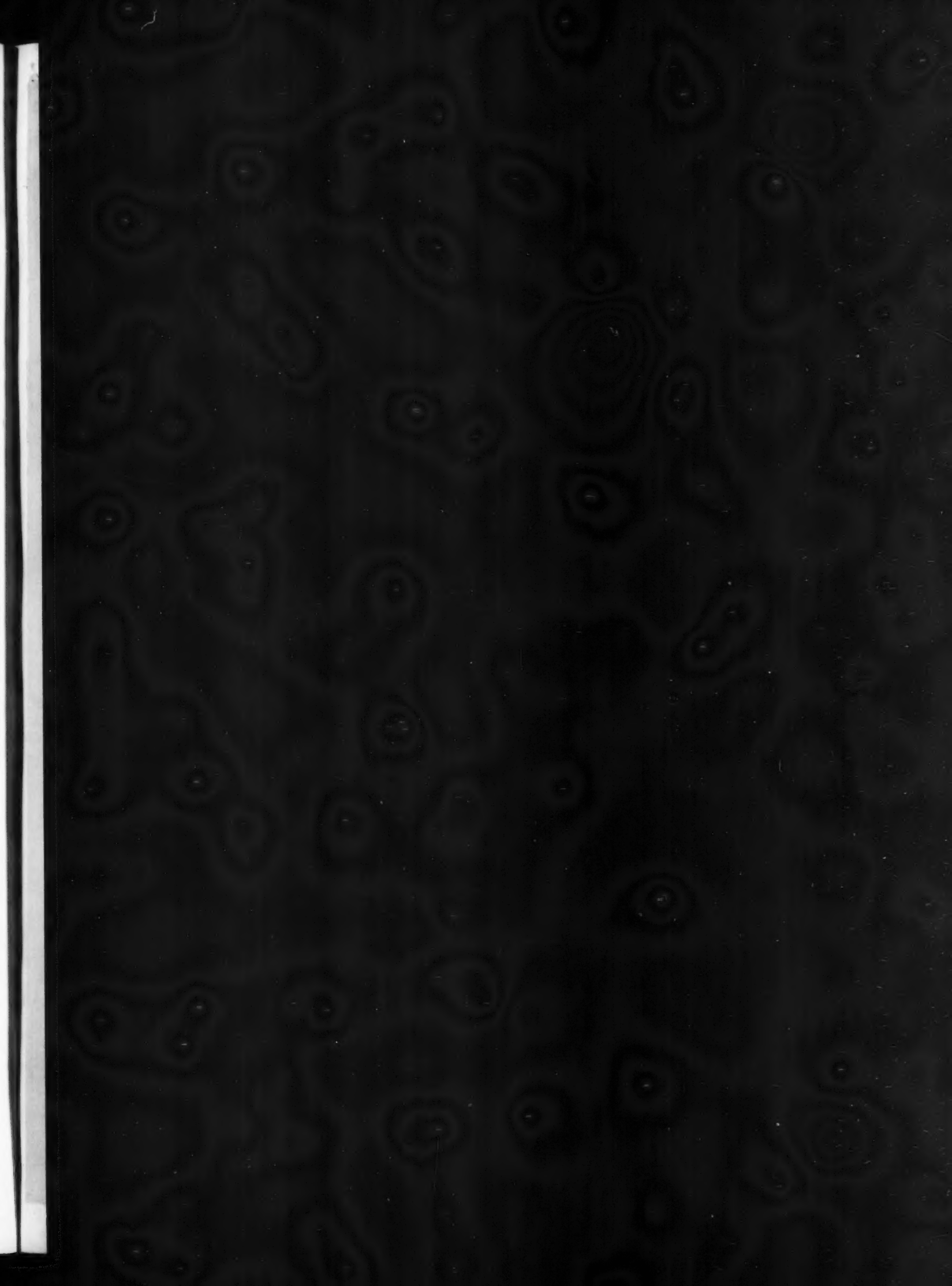
The amount of oil burned, with variations of load, is controlled by the pressure of oil at the oil pumps, the intensity of fire increasing and decreasing in all boilers simultaneously.

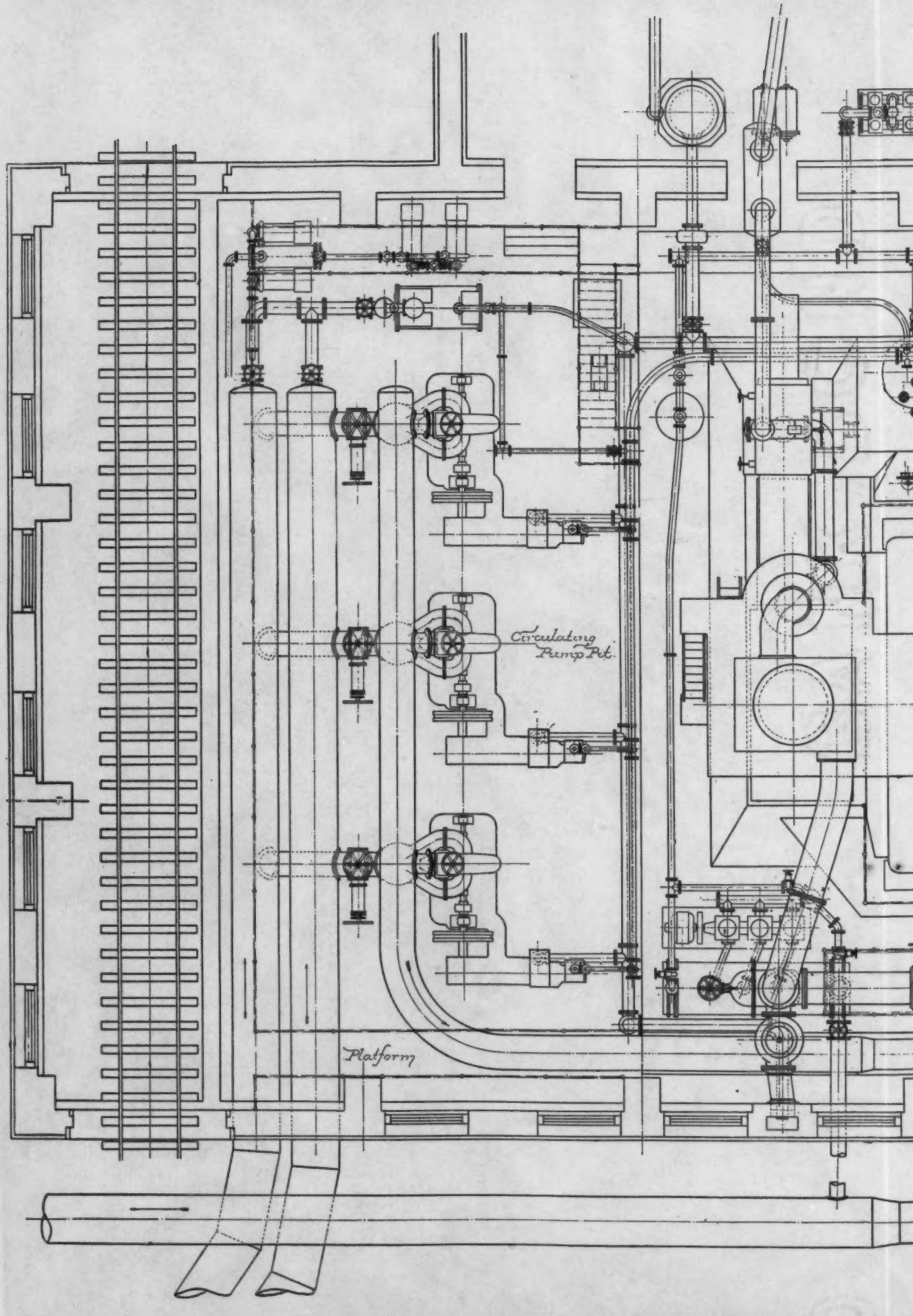


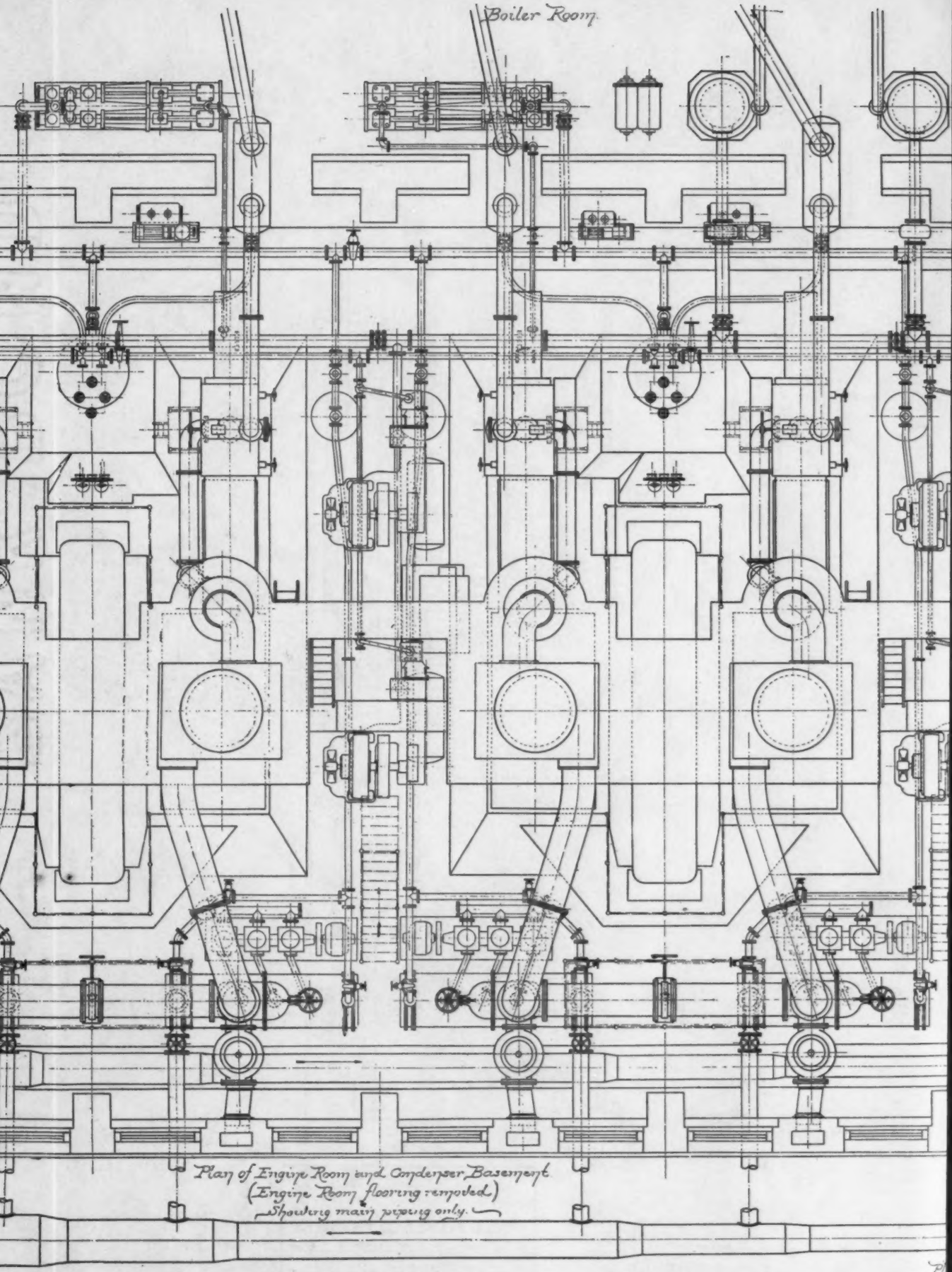
Sectional Elevation Through Boiler, Showing Oil Furnace, Superheater, Overhead Piping, and Concrete Flue

The oil pressure is automatically controlled by a steam pressure regulator, the variations in oil pressure and intensity of fire being such as to maintain a uniform steam pressure on the plant.

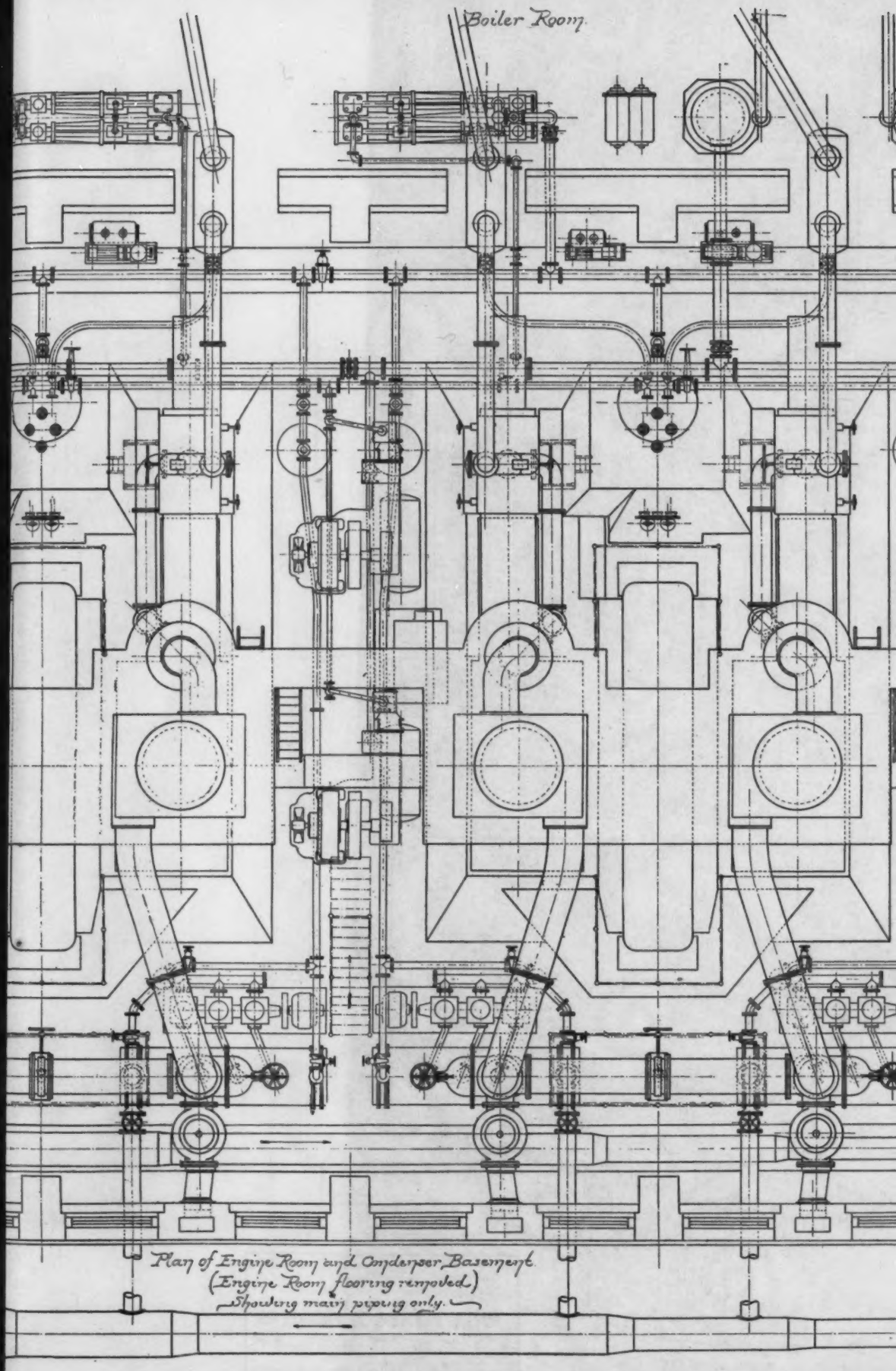
Steam to oil burners, for atomizing purposes, is supplied by a separate low pressure main, the pressure in this main being automatically controlled by variations of oil pressure in the oil main. A ratio regulator is used, automatic in its action, operating to maintain such steam pressure in the low pressure steam main as is necessary to atomize the particular amount of oil burned, corresponding to any momentary oil pressure. In this particular plant, it is found that the proper amount of steam for atomizing purposes is furnished under a steam pressure equal to three times the oil pressure plus 30. This relationship will vary with the type of burner used, relative areas of burner orifices for steam and oil.



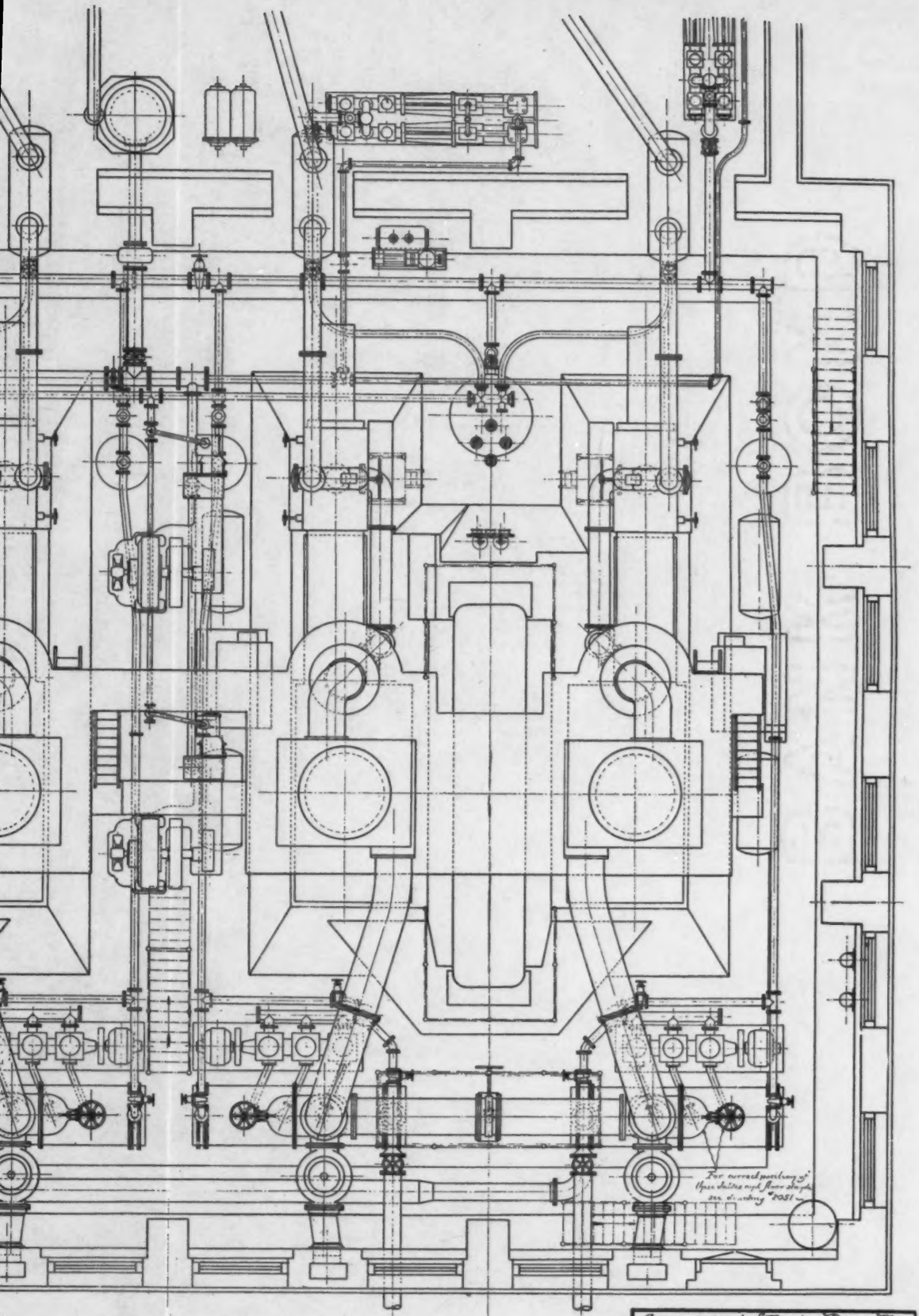

Circulating
Pump Pit
Platform



PLAN OF ENGINE ROOM



PLAN OF ENGINE ROOM



For current practice of open shelter roof floor design see drawing #2051.

Plan of Boiler Room, see drawing #2360.
Elevation of Engine and Boiler Room, see drawing #2361.

Arrangement of Engine Room Plan
1500 K.W. Power Plant, Redondo.
Pacific Light and Power Co.
Los Angeles, Cal.

CHAS. C. MOORE & CO, ENGINEERS.

LOS ANGELES & SEATTLE — MAIN OFFICE SAN FRANCISCO. — SALT LAKE & NEW YORK

DRAWN BY	C.H.P.L. & O.K.D.	SCALE	1/4 in = 1 FOOT
CHECKED	C.J.A.	DATE	February 19, 1907
APPROVED	C.C.M.	DRAWING No.	2359.

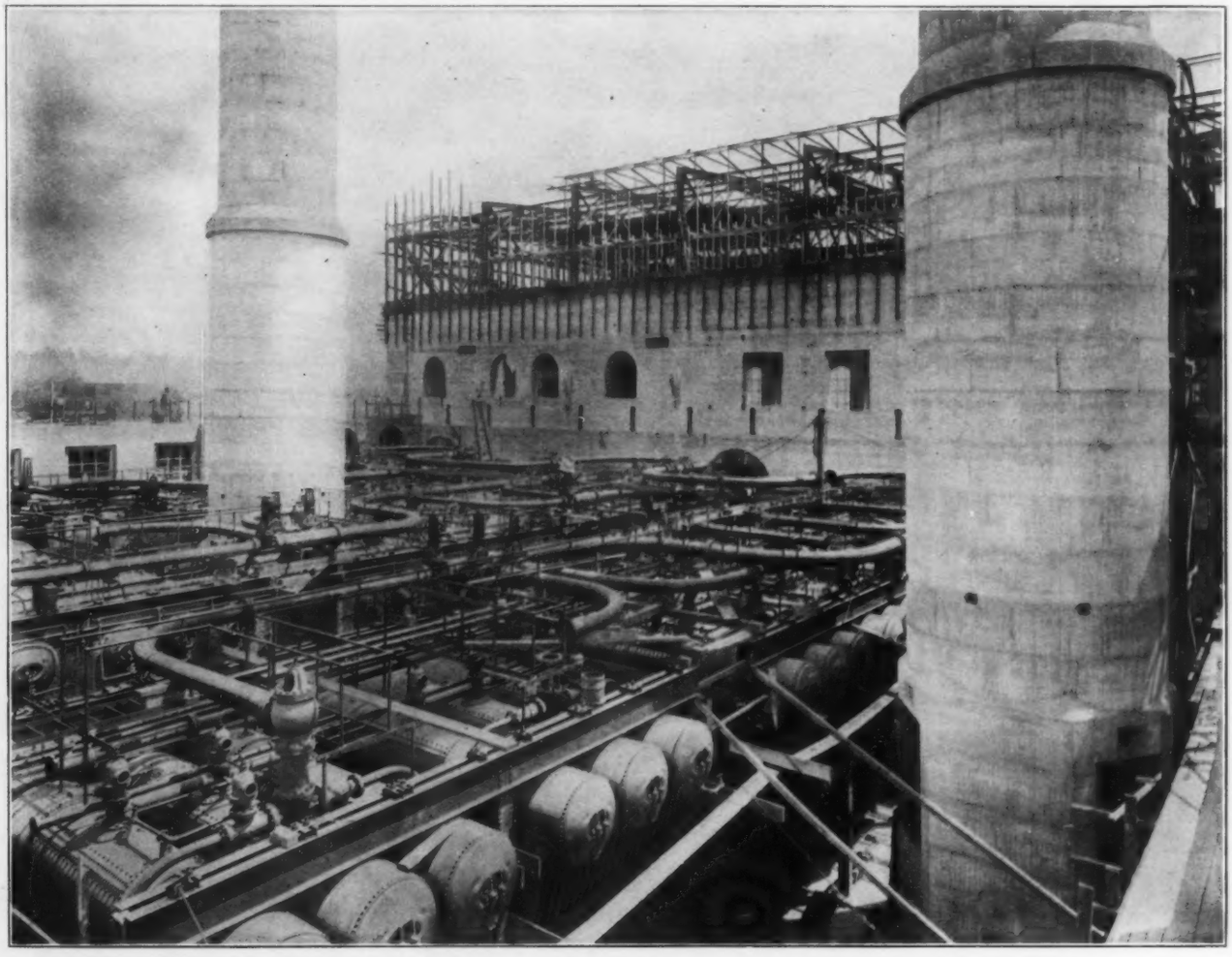
The air supply for combustion is controlled by a damper controller, also automatic in its action, which increases the damper opening with an increase in oil pressure and vice versa. The movement of the controlling lever is due to the oil pressure acting on a diaphragm. This movement is opposed by the action of a spring, such that the amount of movement on the main lever is proportional to the oil pressure. This movement is multiplied through a hydraulic cylinder connecting to a rock shaft running over all of the boilers in one panel. Each boiler damper is connected to this shaft. The connecting levers are set at such angularity, with respect to the connecting rods operating the dampers, as to give the proper air supply for the various ranges of load, the final adjustment being from actual trial at the plant.

In actual operation and test, it is found that this automatic system of control is safe, reliable and meets with the approval and hearty endorsement of the firemen. Owing to the fact that the firemen's work is very much simplified by the use of these regulators, they are as much desired by the firemen of the plant as by the management; and were it not for this accord, such automatic contrivance could not be successfully installed and operated by the class of labor met with in the ordinary fire room.

A detailed description of this novel system of automatic regulation for oil firing will be made the subject of a special article to be published at a later date.

FEED WATER FILTERS:

The air pump discharge is pumped through six marine type feed water filters, 48″ in diameter, 5 ft. in height. Each filter has five compartments of filtering material, suitable for the elimination of the greater portion of entrained cylinder oil. In the operation of this filter the discharge is into the top of the filter. The water passes down through the filtering material and out at the bottom to a stand pipe, maintaining a complete submergement of the filtering material. Owing to the slow velocity of the water through the filter, there is a tendency for any oil, not absorbed by the filtering material, to rise to the surface rather than to be carried on and into the boilers by the downward flow of water.



Boiler Room—Showing Main Steam Piping

PIPING SYSTEM:

The general arrangement of main steam piping is shown on the accompanying drawings. All of the piping of the plant except for some of the minor auxiliaries, is arranged on the panel system, dividing the plant into three independent units. In the lay-out of this station it was desired to reduce the diameter of steam mains. On each high pressure cylinder of each engine, the throttle valve is for 14″ pipe. Owing to the necessity for long radius bends, and the desire for flexibility, it was determined not to employ any steam pipes over 14″ in diameter. It was finally decided to connect three boilers in each battery to each side of each unit; thus providing a greater flexibility of service without increasing the cost

of the piping system; hence, in so far as the main steam piping is concerned, the plant can be considered in effect six independent units. The main steam piping was anchored to the building walls and building columns located with this idea in view. It was found, however, that the columns were not sufficiently rigid for anchorage purposes, and it became necessary to install a cross system of bracing from wall to wall. Drainage is afforded by locating a large receiver drum in each line of piping, as shown in the drawing.

In all high pressure steam piping 5" diameter and over, up-set lapped joints were used with rolled steel flanges, being an improved type of Van Stone joint. Bolting and thickness of flanges was very conservatively designed in order to prevent leakage, and in this respect the contractors have succeeded in making an absolutely bottle tight system of piping.

As but a moderate degree of superheat is required, the valves and fittings are of semi-steel, have bronze mountings, and Detroit-Edison necks to prevent leakage of steam around valve spindles, etc. Chapman Valve Mfg. Co.'s valves were furnished throughout the plant.

Special consideration was given to the design of exhaust piping to provide the most direct course from the engine to the condenser. As will be noted in the drawing, there is but one bend between the engine exhaust outlet and the condenser inlet and this is of exceptionally long radius. Exhaust pipes have been made of large diameter to lower the velocity of exhaust steam and under actual test the loss in vacuum between the condenser shell and exhaust nozzle was at all times less than ½" mercury column.

The plant is complete with modern arrangements for handling and storing cylinder oil, filtering oil, etc. Compressed air is used to deliver the filtered oil to the various parts of the plant.

All high pressure steam piping is covered with non-conducting covering 3" in thickness, there being valve body and flange covers throughout. The effect of this heat insulation has been to greatly economize the pipe radiation.

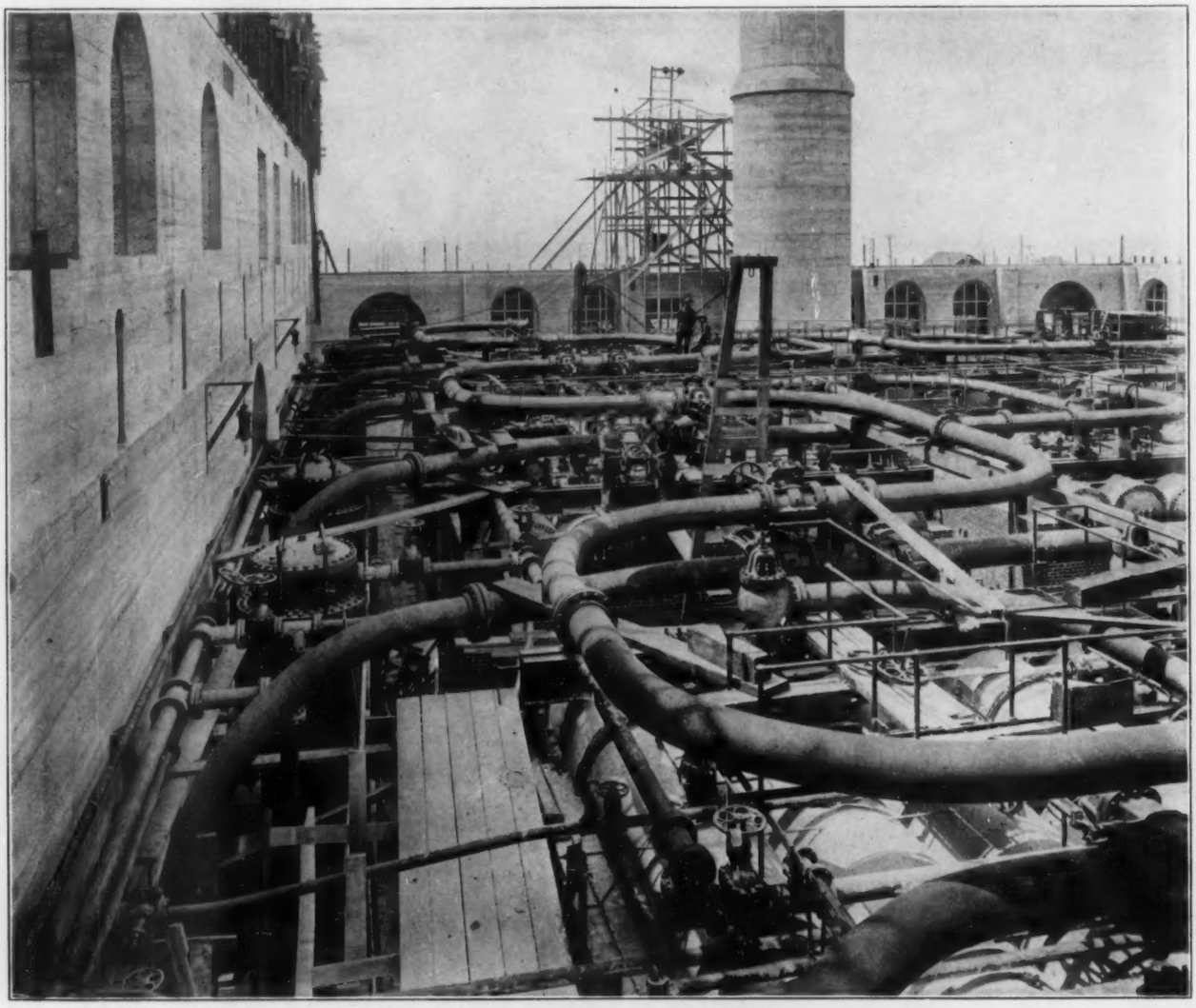
NON-CONDUCTING COVERING:

In pump pit has been installed an Underwriters' Fire Pump, fitted for salt water. This pump also serves as a pressure pump furnishing pressure water for the Lagonda power driven cleaner for boiler cleaning purposes.

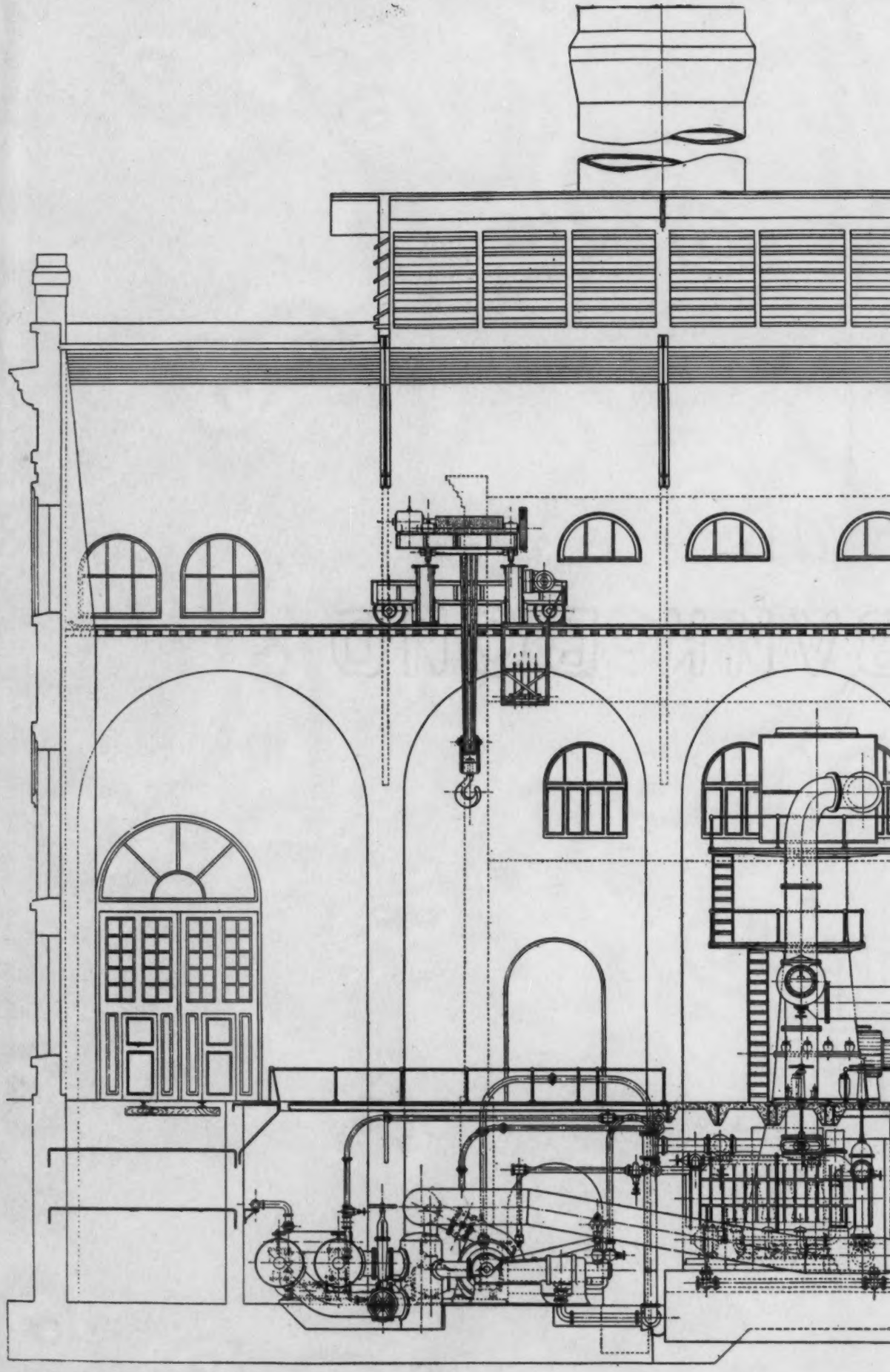
FIRE PUMP:

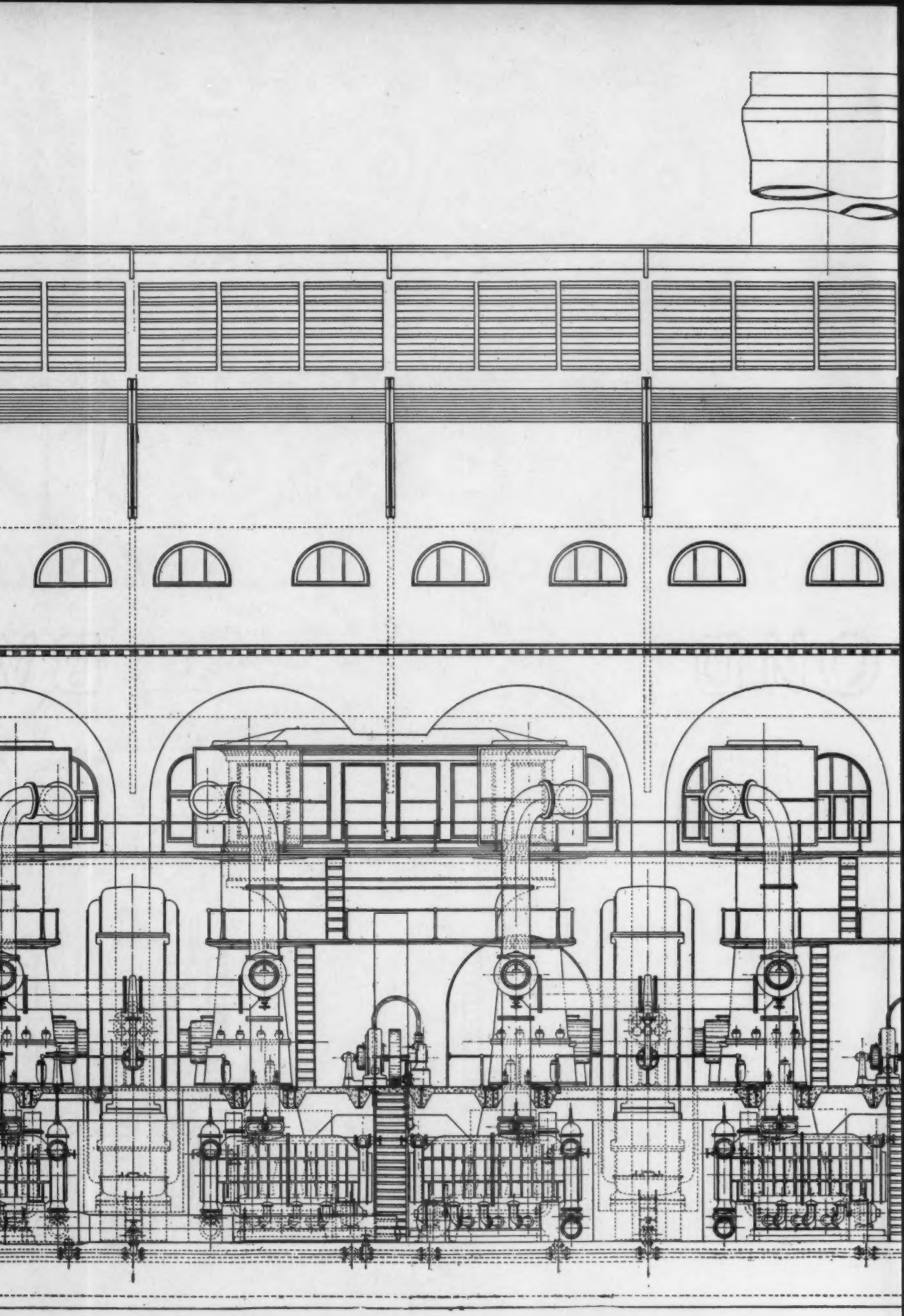
For the purpose of providing circulating water for cooling main engine bearings and guides, which are hollow, designed for such cooling, a set of circulating pumps and inter-cooler have been furnished. Fresh water is circulated through the engine parts and is cooled by means of a small surface condenser; the fresh water for cooling flows

COOLING SYSTEM FOR MAIN ENGINE BEARINGS:

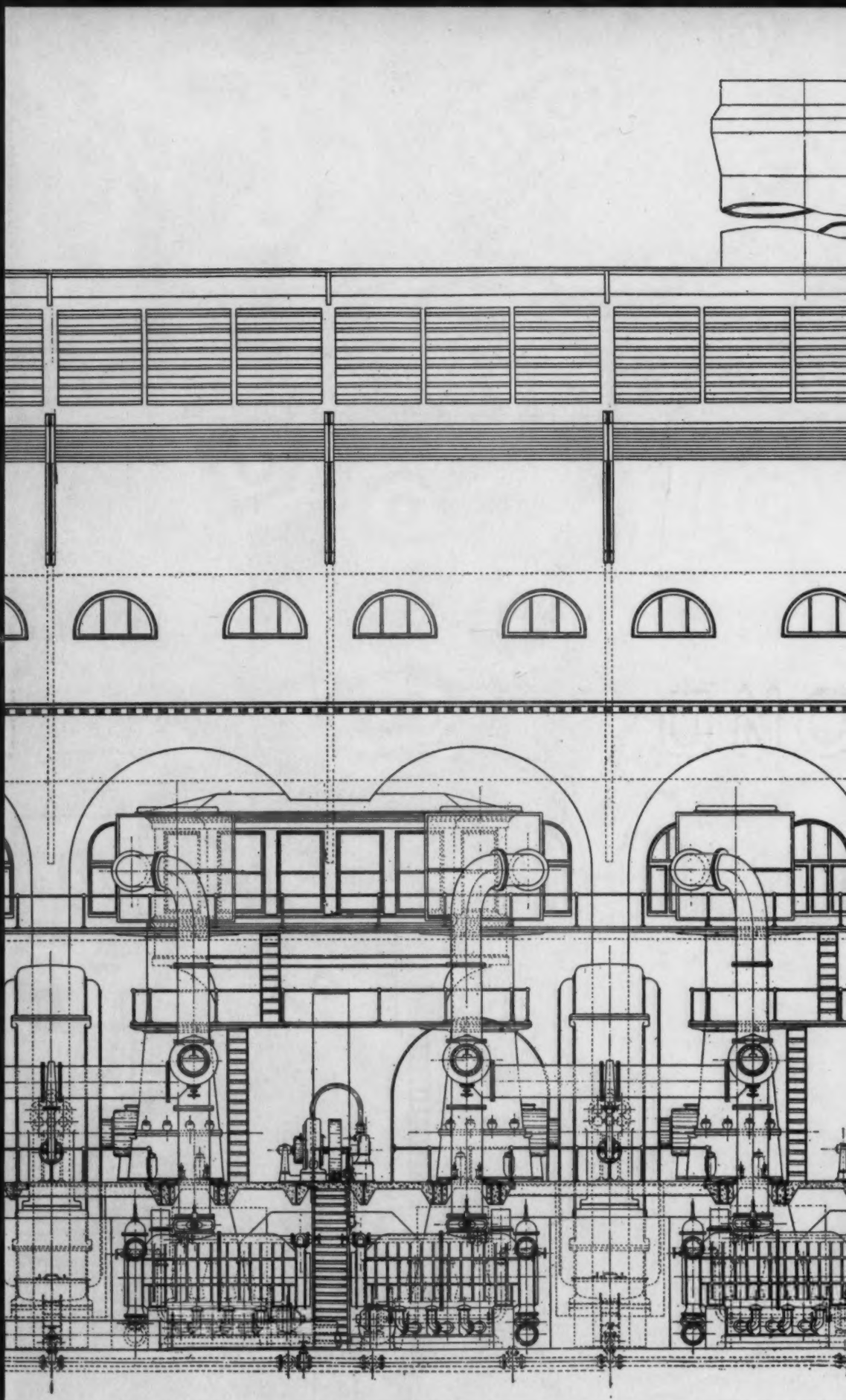


View of Boiler Room Piping During Erection

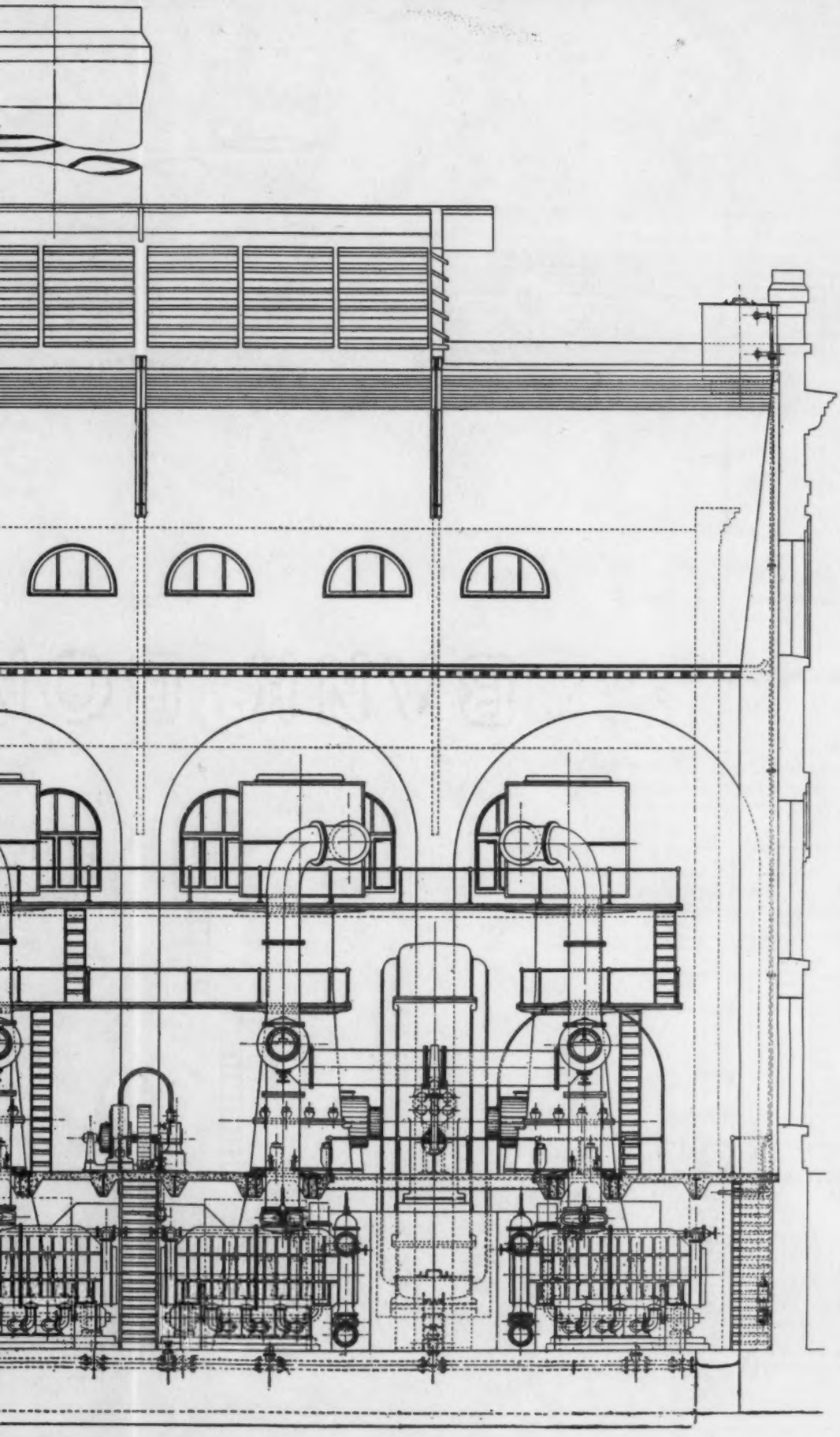




LONGITUDINAL ELEVATION OF ENGINE ROOM



LONGITUDINAL ELEVATION OF ENGINE ROOM

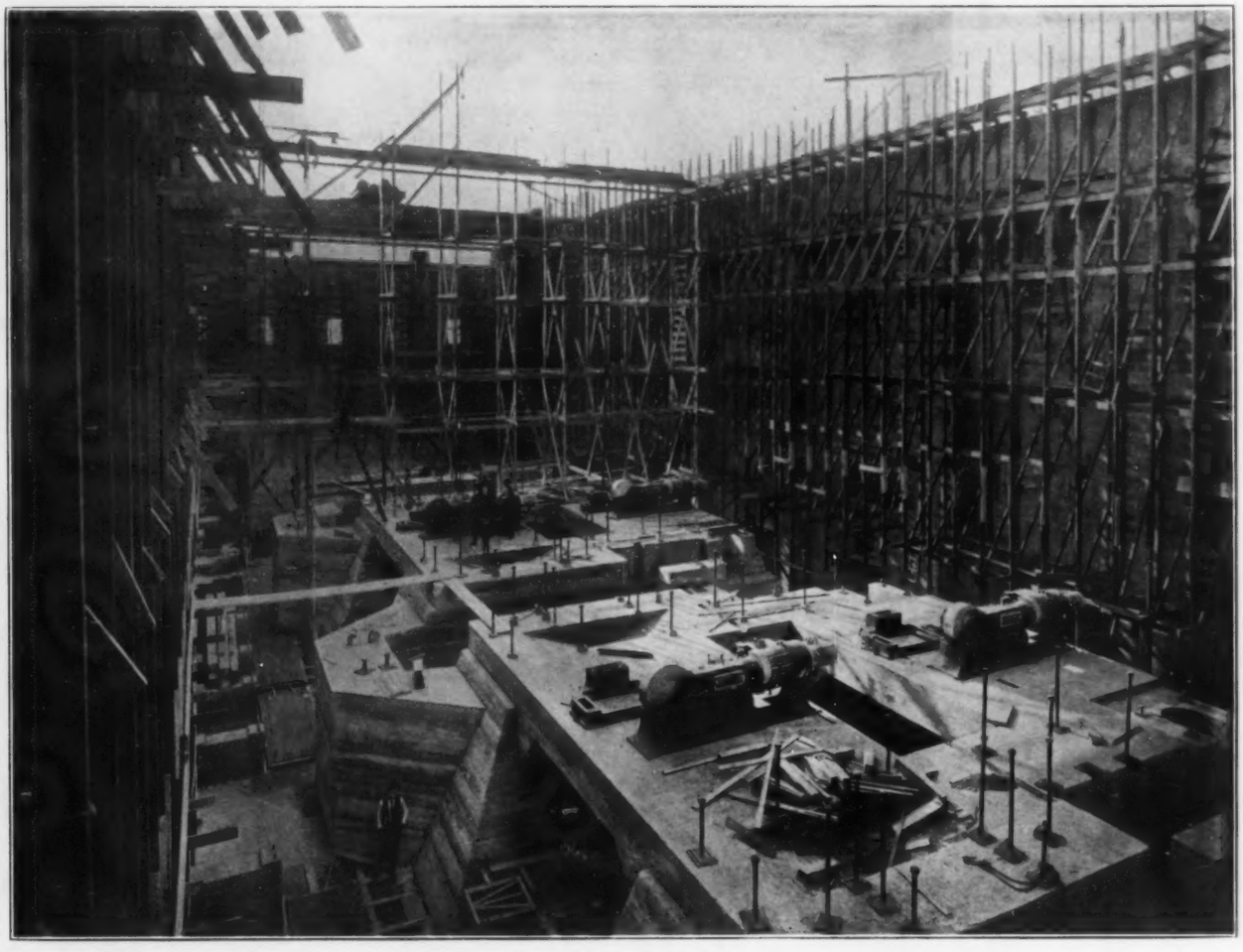


within the tubes and salt water is circulated around the tubes, being taken from condensing water suction mains.

CHIMNEYS:

There are two reinforced concrete chimneys each 13 ft. diameter, 125 ft. in height. Each chimney is of capacity for two units, the plant being so arranged that a fourth unit may be added to the station and connected to the second chimney.

The chimney gases pass from boiler to chimney through specially designed reinforced concrete flues; these have proven eminently satisfactory for the work, although slight heat cracks appear in the concrete in various places.



View of Engine Foundations

ENGINE ROOM CRANE:

For convenience in erecting and handling machinery there was installed a 62½ ton Nile-Bemont-Pond electrically operated engine room crane. Railroad tracks allow cars to enter building at one end, heavy machinery being unloaded by crane direct to engine foundations.

FOUNDATIONS:

The plant is installed on the beach within a few hundred feet of the surf line. The sub-soil consists largely of drift or pit sand.

In order to prevent vibration due to the main engines, the design of sub-foundation was carefully studied. It was finally determined that in lieu of piling, there would be constructed a sub-foundation 6 ft. in depth the entire length and width of the engine room, except a 2 ft. space all around to prevent interference with building foundations.

This slab is reinforced top and bottom at the critical points. The main engine foundations were built directly on top of this slab rising 14 feet to the engine room floor line. Foundations for exciter engines were made by arching over the space between adjacent units suitably strengthened with reinforcement, thus affording ample space underneath for rheostats, filters, etc. Photographs are here reproduced showing the main engine foundations complete.

Real Estate restrictions made it necessary to locate the plant at some distance from the ocean. The shallow beach line made it further necessary to carry a wharf built some distance into the ocean in order to obtain the necessary depth for suction at low tide. The centrifugal circulating pumps are located in the pump pit, the center of pumps being about 12 feet above mean low tide. The combined suction and discharge piping comprises a length of 1700 feet.

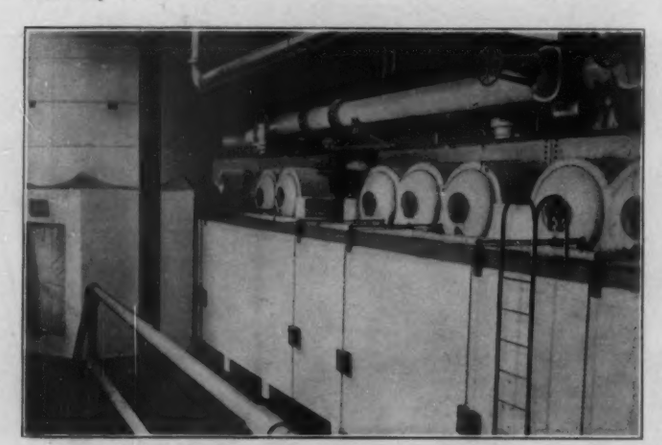
CIRCULATING WATER SYSTEM:

The circulating system consists of two suction pipes 50" in diameter made of sheet steel. There is but one discharge line 50" in diameter. The suction intakes are open ended, the strainers and the sand settling tank being located at the beach end of wharf.

As ocean surf is impregnated with air which must be removed from the suction line under vacuum, and further, in order to prime the suction line before starting, after periods of cleaning, a large duplex motor driven vacuum pump was installed. This vacuum pump removes the air by means of a stand pipe rising 40 ft. above tide, located at the high point of the line.

GENERATORS:

The three main generators manufactured by the General Electric Company, are of particular interest on account of the extremely high voltage, 18,000 volts, for which they are wound. These generators are rated ATB—60 poles, 5000 Kw., 100 RPM—18,000 volts, 50 cycles, three phase, and are of the engine driven, fly-wheel type. The following data may be of interest:—



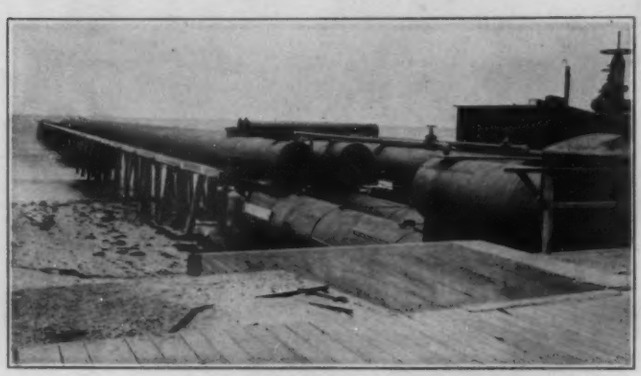
Chimney and Breeching both of Reinforced Concrete

Floor space required ...	.....31 ft. by 6 ft. 9 in.
Diameter of Stator	.....28 ft. 6 in.
Diameter of Rotor	.....25 ft.
Radius of Gyration	.....8.8 ft.
Weight of Stator	.....186,000 lbs.
Weight of Rotor.....	.....162,000 lbs.
Weight of accessories ..	..... 12,000 lbs.
Total weights	.....360,000 lbs.

The commercial efficiencies at unity power factor are as follows:—

1.25 Load	.....96.5%
Full "	.....96.2%
0.75 "	.....95.2%
0.50 "	.....93.5%
0.25 "	.....88.0%

The armature coils of these generators have stood a high potential test of 40,000 volts for one minute.



Circulating Water Suction and Discharge Line to Ocean

On account of the severity of the specifications in regard to the operation of these generators in multiple with existing apparatus on the transmission system of the Pacific Light & Power Co. the revolving fields are provided with a squirrel cage winding to prevent hunting.

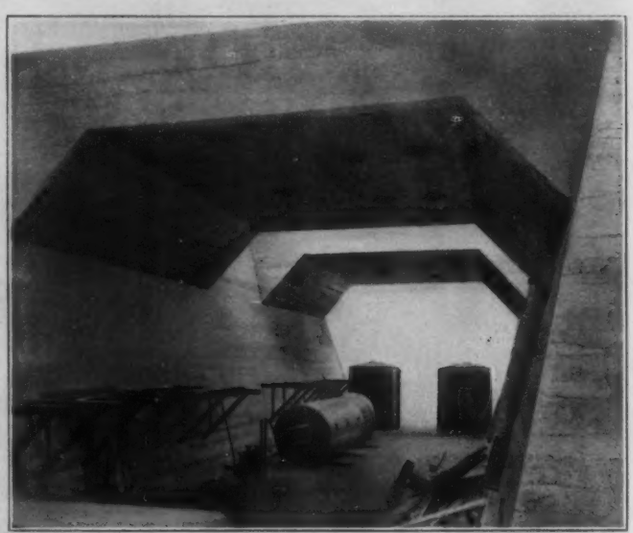
The generator field rheostats are motor operated, with remote control from the switchboard.

The starting, stopping and loading of the various units, is controlled entirely from the switchboard gallery, located above the boiler room and along side the main engine room wall.

SWITCH BOARD EQUIPMENT:

The following description of switch-board gallery was furnished by E. R. Davis, Electrical Engineer for the Pacific Light & Power Company :—

"The generator wiring between the generators and switchboard room consists of three 4/0 bare copper wires, each in a separate duct, on large porcelain insulators. In connection with this we installed one spare duct and spare cable for use in case any of the three main lines break down or become defective. Each generator is connected through 2-way porcelain mounted selector switches to either of two sets of high tension bus bars; these bus bars being located in two separate concrete galleries. The feeders, two each to the L. A. Ry. Co. and the P. E. Ry. Co., are also connected through 2-way porcelain mounted selector switches to either of two sets of high tension bus bars, the purpose being that we may be able to kill and repair oil switches, insulators, etc., in either bus bar gallery without interfering with the operation of the gen-



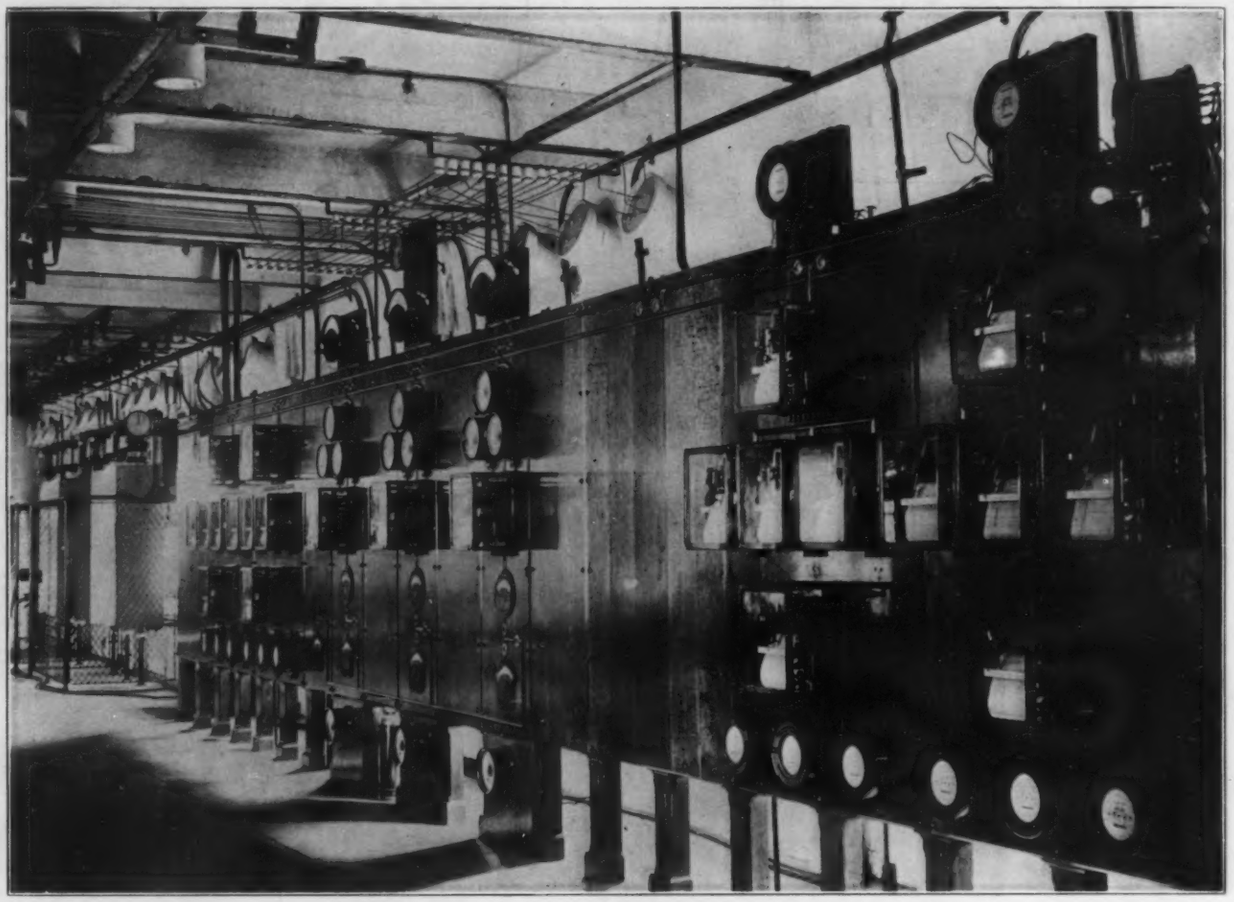
Concrete Arches Between Main Engine Foundations Supporting Exciter Engines

erators or the distributing feeders. The oil switches are the single cell, single throw, 4 break, 400 ampere switch, mechanically connected together in gangs of three poles. These switches are operated by manual remote control, and the entire equipment was built in the shops of the Pacific Light & Power Co. The operating stand and the instrument board are made from well seasoned oak, the object of using wooden construction in this particular being partly due to the saving in expense in building wooden structure instead of marble, but principally due to the fact that on account of the rapid progress of electrical science our switchboards rapidly become obsolete, and if made of marble they would be extremely expensive and hard to replace. With reference to the danger from fire hazard in connection with wooden structure, beg to state that all the high tension alternating current wiring is communicated to the switch-board instruments through the low tension wiring of current and potential transformers, said low tension wiring being permanently grounded; approximate voltage on same being 120 volts. The alternating current instruments used in connection with the feeders and generators on this switch-board are the curve tracing Westinghouse

graphic recording type. The exciters and field circuits are equipped with Weston D. C. instruments.

"The lightning arresters in connection with this station were furnished by the General Electric Co.—two sets in connection with the contract from your people, and the second two sets purchased by ourselves at a later date.

"The exciters, four in number, are wired up to the marble switch-boards located on the main engine room floor, the switches being operated by remote control, using air for this purpose. The wiring is so designed that under ordinary conditions each main unit has its independent exciter, and should anything happen to the particular exciter, the fourth or spare exciter, might be connected to any of the main units.



View of Switchboard

"Field rheostats in connection with main generators are motor driven for remote control.

"The auxiliary induction motors in connection with the Edwards Air Pumps, small circulating pumps, condenser and feed water motors are operated from a bank of step-down auxiliary transformers connected to the main generator leads.

"Will state that the operating room and galleries consist entirely of reinforced concrete construction and are in every detail entirely fire proof."

FEED WATER PURIFIER: The make up water for the plant is supplied by wells on the property of the Company. This water contains certain carbonates and sulphates and is purified before being supplied to the plant by means of an automatic purifier.

BUILDING: Building, foundations, wharf, and circulating water pipe line, were designed and installed under the direction of Edwards S. Cobb, Chief Engineer for the Pacific Light & Power Co. The building is entirely of reinforced concrete, erected by Carl Leonardt, a prominent Southern California contractor. In design of the power plant building, the elements of economy and simplicity were given first consideration, although a decidedly pleasing architectural appearance has been maintained throughout. For its purpose of use, the power plant building is unquestionably the most appropriate of any in the West.

The installation of machinery and the erection of building proceeded at the same time. The engine crane was erected as the side walls were carried up. It became necessary in hastening completion to use the crane before the roof and roof bracing was in place. With concrete less than 30 days old the full weight of 135,000 lbs. live load was carried by the crane the length of the building, without injury to the concrete, a remarkable performance.

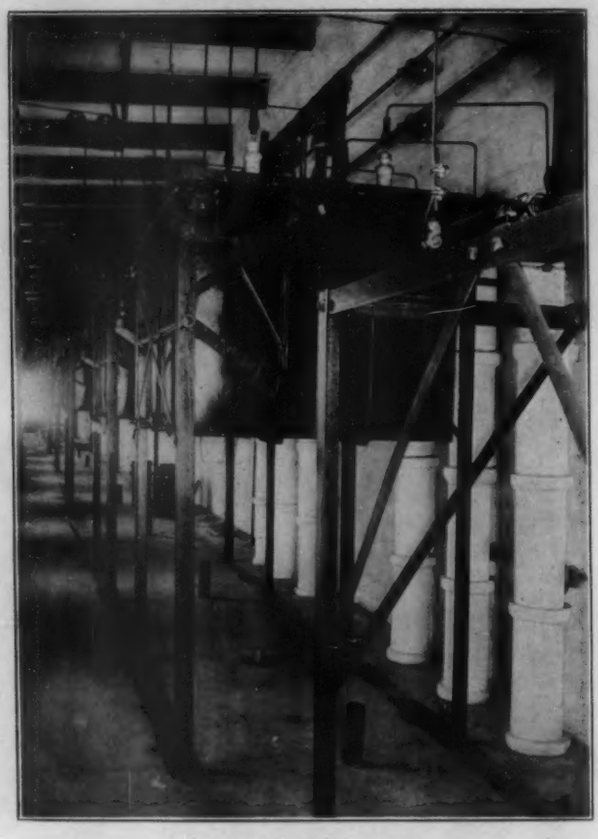
OPERATION OF PLANT: Various practical difficulties were met with in starting the plant naturally to be expected in any installation of large size. The entire crew were inexperienced in the handling of machinery of anything of more than one-quarter the size of this station. The difficult task of breaking in the crew, and the operation of the plant was entirely

under the direction of Mr. J. R. Atchison, Superintendent of Construction for the contractors, Chas. C. Moore & Co. Engineers, under whose charge the installation work also proceeded.

While the load was carried from the start without serious interruption, it was not until after some time that the operators were thoroughly systemized and familiarized with their respective duties.

Lightning Arresters

While it is the usual practice under Pacific Coast conditions to attempt to filter cylinder oil out of air pump discharge it is contrary to the experience of Eastern stations and represents probably one of the most radical departures from Eastern practice in the design and operation of this plant.



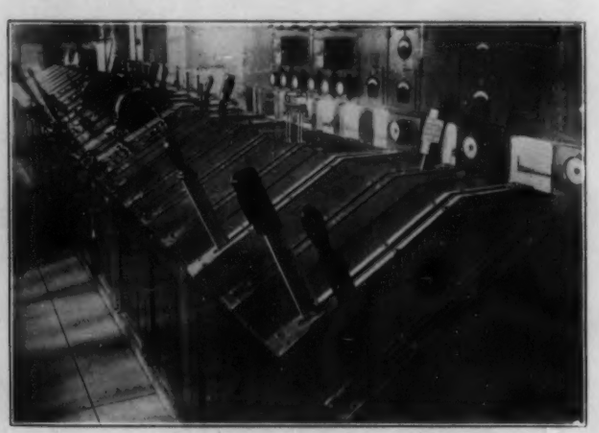
High Tension Switch Gallery

One of the difficulties yet to be solved by the Pacific Light & Power Company, is the elimination of sea weed, and more particularly the fine sea moss from the circulating water which fouls the condensers and gives rise to a frequent loss of vacuum, compelling operation non-condensing. It happens that in the warm climate throughout the entire southern country, there is a large marine growth, consisting not only of kelp but also the finer grades of sea moss; it is impracticable to handle this effectively with any type or make of enclosed strainer. It is probable that some type of open canal screens will be used to remove this most objectionable difficulty.

Some very interesting results have been accomplished at this station in the handling of condensing apparatus during difficulties with sea weed.

As stated above, there are supplied two condensers for each unit. The entire exhaust steam from one unit has been handled by one condenser, the other condenser being temporarily out of service, due to the accumulation of sea weed; the loss of vacuum due to this overloading of one condenser varies from 1½ to 2".

The operation of the Volz heater acting as a primary heater raising the temperature of the air pump discharge is quite effective and results in material fuel saving.



Switchboard and Operating Table

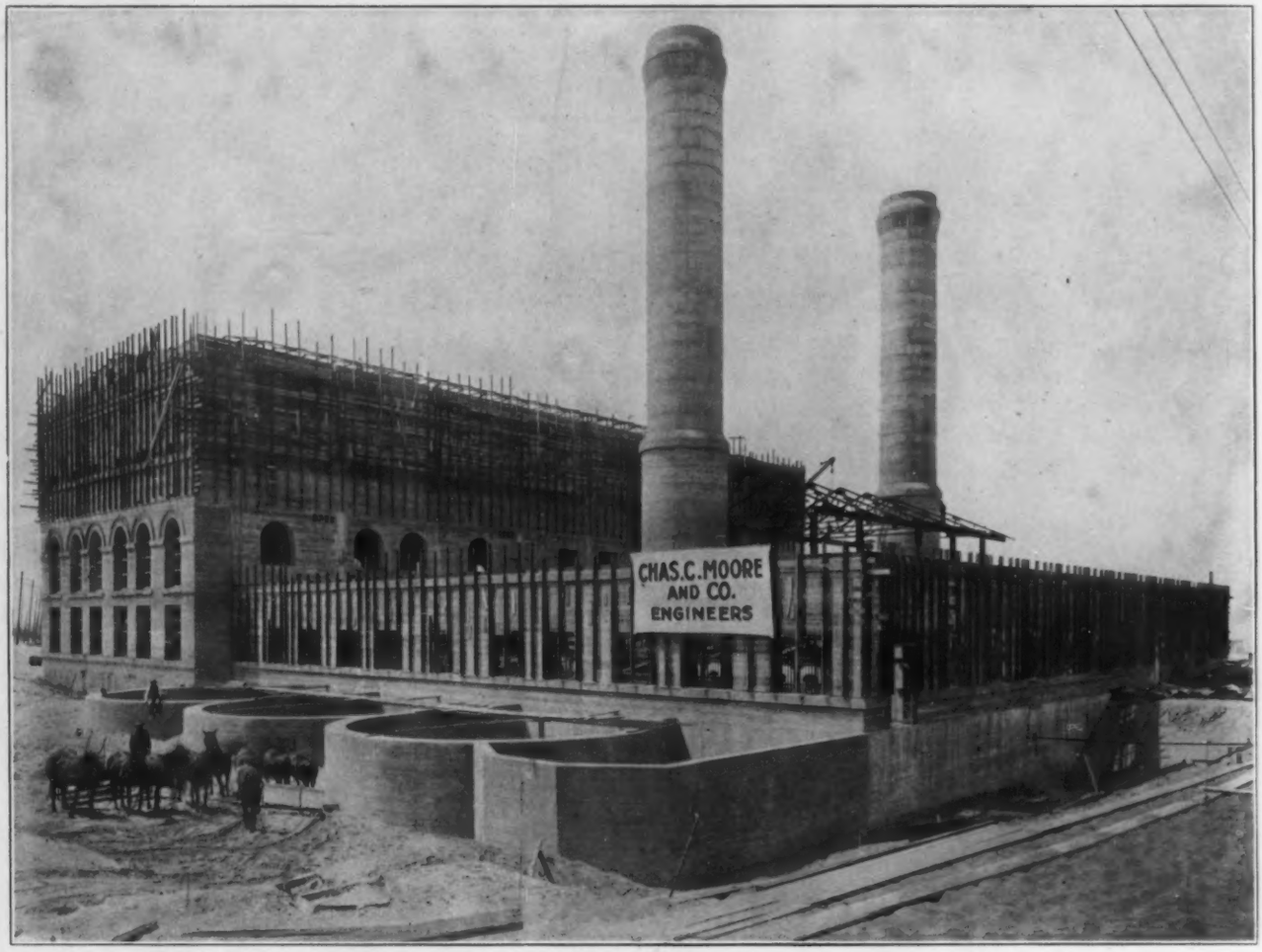
The circulating water system was designed to operate on the syphon system, requiring but a nominal head of from 15 to 20 ft. on pumps. This head at times of accumulation of sea weed would rise to 35 ft. and more. Even with the quantity of auxiliary exhaust steam due to this head, the amount is below the capacity of the feed water heater, so that no exhaust steam is wasted under any normal condition of run ning.

The contract covering this station embodied an economy guarantee providing for a 90 days test of one unit on a commercial railway load, under any load curve within the limits of the rated capacity of the generator, the total output being not less than 60,000 K. W. hours, nor more than 78,000 K. W. hours per 19½ hours running, there being 4½ hours stand-by each day.

GUARANTEE:

On this load the Company guaranteed an economy of 170 K.W. hours per barrel of oil; each barrel weighing 334 lbs., each pound containing 18,500 B.T.U. The contract provision for a 90 days test was subsequently modified to cover a period of 15 days in view of the fact that the test was not under way until after six months operation of the plant, when running conditions had presumably become normal.

To determine the economy of the plant the contracting parties each appointed a representative, the two jointly selecting a neutral party. The representative for the Pacific Light & Power Company was Edward S. Cobb, Chief Engineer. The representative for Chas. C. Moore & Co. Engineers, was C. R. Weymouth. The neutral member of the Testing Committee was Prof. C. L. Cory, Dean of the College of Electrical Engineering, University of California. Mr. Cobb was assisted by Mr. Edward R. Davis, Electrical Engineer for the Pacific Light & Power Company, and Mr. Weymouth was assisted by Mr. G. C. Noble, Prof. of Electrical Engineering of the University of California, Mr. J. N. LeConte, Prof. of Mechanical Engineering, University of California, and Mr. H. W. Beecher.



Building in Course of Erection. Oil Storage Tanks in Foreground.

Also there were present as contractors' representatives, Dr. D. S. Jacobus, Advisory Engineer for the Babcock & Wilcox Co., Mr. Harte Cook, Testing Engineer for McIntosh, Seymour & Co., and Mr. J. A. Lighthipe, Engineer for the General Electric Co.

The test was one of the most elaborate ever undertaken in connection with a steam power plant. The expense amounted to many thousands of dollars, there being engaged in the work including the three shifts, for the three parties of interest a total of about eighty men.

The Committee's report gave the result of the 15 days test as 252.842 K.W. hours per barrel of oil. There is in this result a slight correction in favor of the contractors due to an excessive sulphur and moisture content of the oil. This record eclipses all published statements of economy of large power plants, operating under commercial conditions. For purposes of comparison with Eastern results, the above economy is equivalent to slightly less than 25,000 B.T.U. in the fuel per K.W. hour net output of plant.

It should be stated that this test was made on a complete unit with the exception of the circulating water pump. The actual head under which the plant now works due to sea weed difficulties, varies from 30 to 35 ft. The contract provided that the Purchaser supply a syphon system of circulating water piping, so that the total head of friction and flow would not exceed five feet. An allowance was made for the omission of the circulating pump by deducting from the total bonus earned a suitable sum. It can be safely stated that the reduction in economy due to the energy to drive circulating pump would have been a small fraction of 1%, particularly in view of the fact that all of the exhaust steam would have been utilized in the feed water heater.

The bonus earned as a result of the above economy was $363,310.00, which is undoubtedly the largest bonus ever paid on a steam power plant guarantee.

At the time this contract was closed it was necessary that the Purchaser have substantial protection as to the cost of power produced by this station, the plant output being contracted in advance at rates calculated from economy guaranteed, which in itself was in advance of any economy then realized with fuel oil. While none expected such an unprecedented gain over the stated economy, yet from the very nature of its business, sound business policy offered to the

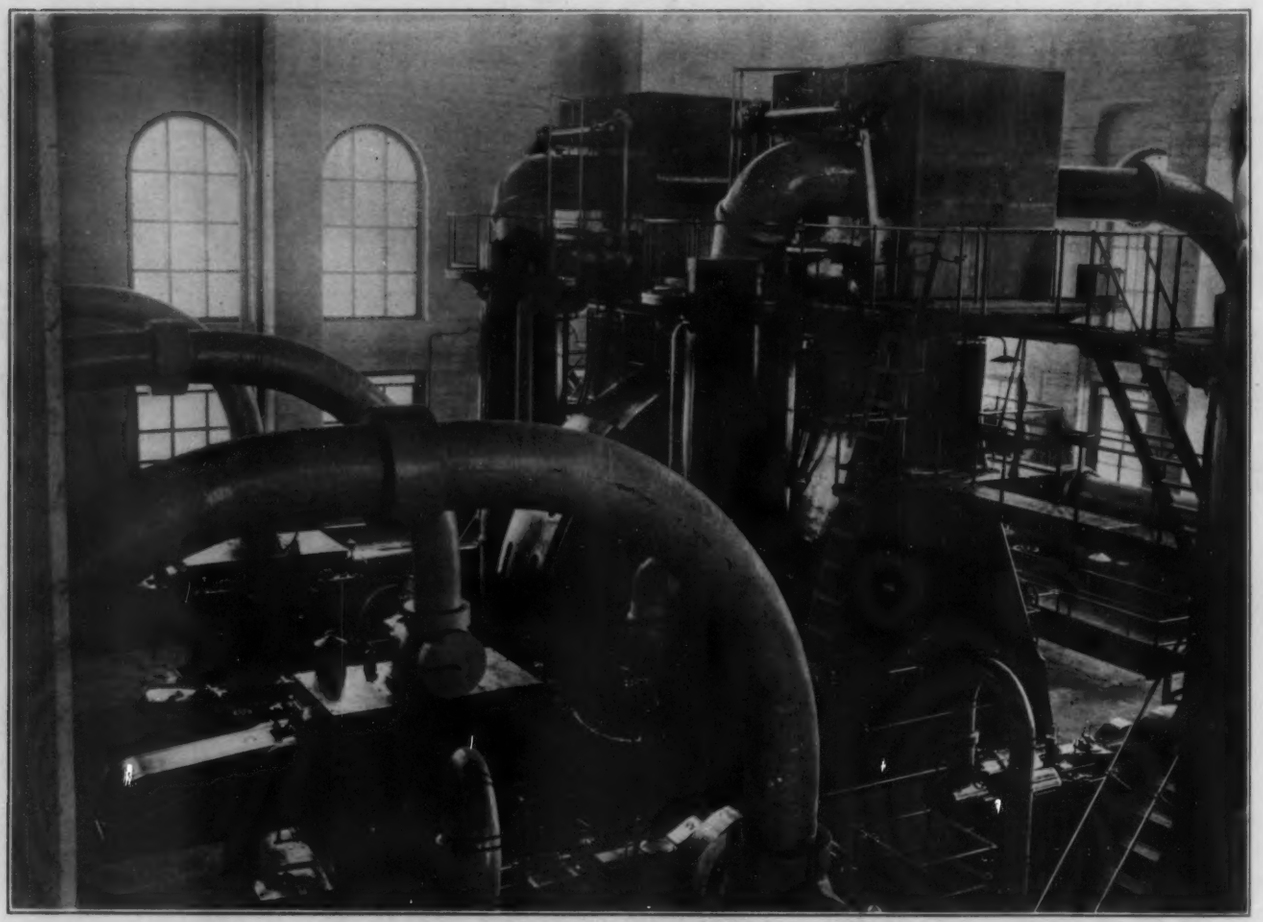
management no alternative than these guarantee stipulations.

Based on the local market price of crude oil, the fuel saving due to this gain in economy will pay the full amount of bonus, in from two to three years' time, thus making this bonus a gilt-edge investment; the saving during the remainder of the life of the plant representing an enormous gain for the Purchaser.

REPORT TESTING COMMITTEE As a matter of interest the report of the Testing Committee is appended :—

Los Angeles, Cal., June 4, 1908.

Pacific Light & Power Co.
Los Angeles, Cal.
(Hereinafter called the Purchaser.)
Chas. C. Moore & Co. Engineers,
San Francisco, Cal.
(Hereinafter called the Company.)



No. 1 McIntosh & Seymour Engine After Erection

It may be surprising to Eastern Engineers that a power plant of this magnitude should be undertaken with the use of steam engines in lieu of steam turbines. At the time this contract was drawn, a most careful investigation was made by the Pacific Light & Power Company under the direction of its General Manager, A. C. Balch. As a result of most extensive inquiries and investigations, Mr. Balch determined in favor of reciprocating engines. From the standpoint of economy at least, this selection has been amply justified. On the score of space, the center distance between the engines is 43 ft. Had the exciters been located elsewhere this distance could have been reduced to 35 ft. The first cost of this plant has not exceeded five per cent that of a turbine station.

COMPARISONS WITH TURBINE STATIONS:

DESIGN The Power Plant proper was designed by C. R. Weymouth, in Charge Engineering Department Chas. C. Moore & Co. Engineers; except switchboard, building and other work outside of building.

Gentlemen:—

We, the undersigned, duly appointed Board of Arbitration and Testing Committee, have completed the economy test of No. 2 *Unit at the Redondo Power Plant in accordance with all of the provisions as set forth in Contract between yourselves, accepted April* 12, 1906, *and in accordance with all of the modifications of said Contract, including the following:*

The Company's letter of July 20*th,* 1906, *regarding modification of auxiliaries, and the Purchaser's letter of acceptance of July* 25*th,* 1906*;*

The Purchaser's letter of Jan. 3*rd,* 1908, *regarding the elimination from test of circulating pumps, and the Company's letter of acceptance of Jan.* 8*th,* 1908*;*

The Company's letter of April 8*th,* 1908, *regarding reduction of time of test from ninety days to fifteen days, accepted by the Purchaser same date;*

The Company's letter of Apr. 27*th,* 1908, *regarding change in place of calibration of meters, and the Purchaser's letter of*

acceptance of May 18th, 1908.

The Company's letter of Apr. 14th, 1908, regarding change in number of meters used in test, and the Purchaser's letter of acceptance of Apr. 17th, 1908;

The Purchaser's letter of May 4th, 1908, regarding the omission of final calibration of meters, and the Company's letter of acceptance of May 5th, 1908.

The proceedings and decisions of your Committee have been embodied in the Committee's Minutes of the various meetings, approved copies of all minutes having been furnished to the Company and the Purchaser through their respective Committee members.

The original observations during the test were made by neutral men under the direction of the neutral member of the Committee. Copies of all originals were made by the neutral observers, one set for the Company's record and one set for the Purchaser's record. All original observations have been retained by the neutral member of your Committee.

In the calibration of electrical instruments, the Committee employed Mr. E. F. Scattergood, of Los Angeles, using certain standards furnished by him, certain standards supplied by the Department of Electrical Engineering, University of California, and certain other standards obtained from the Bureau of Standards, Washington, D. C.

The oil determinations were made by Prof. Edmond O'Neill, Department of Chemistry, University of California.

During the test, the energy required for driving the circulating water pump, for delivering oil from the main storage tanks to the weighing tanks, and for delivering feed water from the wells to the plant under a slight pressure, was not supplied by the unit under test, this being in accordance with the provisions of the Contract.

Your Committee have to report that, in accordance with all the provisions regarding the economy test, as set forth in the Contract, and modifications of the Contract as outlined above, and in accordance with all decisions rendered by the Committee in connection with matters to be decided by the Committee, and after making all proper corrections, the average economy was found to be two hundred fifty-two and eight hundred forty-two thousandths (252.842) kilowatt hours per barrel of oil.

Respectfully submitted,

(Sgn.) EDW. S. COBB,
Member for the Purchaser.

(Sgn.) E. R. DAVIS,
Electrical Advisor to
Purchaser's Member.

(Sgn.) C. R. WEYMOUTH,
Member for the Company.

G. C. NOBLE,
Electrical Advisor to
Company's Member.

(Sgn.) C. L. CORY,
Chairman.

Recent Decisions.

An electric light company which negligently turns a current of electricity onto a circuit having a grounded wire is held, in Harrison vs. Kansas City Elec., etc., Co. (Mo.), 7 L. R. A. (N. S.) 293, not to be able to escape liability for resulting injury to a person coming in contact with the grounded current, by the fact that the injury would not have occurred except for the act of a stranger in making a second ground at another place.

GAS PRODUCER TEST.

A forthcoming bulletin of the United States Geological Survey will contain an exhaustive report of the tests conducted at the fuel-testing plant in St. Louis, Mo., and Norfolk, Va., on the gas producer. An interesting feature of the report will be the behavior of a certain bone coal from West Virginia in the producer. This fuel was considered of little or no value for steam boiler work, yet showed considerable usefulness in the gas producer, developing at the engine a brake horsepower per hour for 1.65 lbs. of coal.

This coal was delivered on the producer platform in lump form up to 8 or 10 inches in size. The coal crusher not being available, at the time, necessitated breaking the large lumps with a hammer. The character of the fuel was rather peculiar; some of the lumps consisted almost entirely of what appeared to be a high-grade bituminous coal, others seemed to be nothing more or less than rock, heavy, hard, and when hit in the dark with a hammer numerous sparks could be readily seen. And again there were many lumps of this rock-like substance to which adhered much good coal. In the producer all of these lumps when not too large would burn entirely through. The fuel had no tendency to clinker or coke, and worked exceedingly well, needing scarcely any poking. It contained a very high percentage of ash, about 45 per cent, thus causing the ash bed to increase in thickness very rapidly, and throughout the test this fact was not properly appreciated; consequently, much of the time during the test the ash bed was too high for best results. The fact that the coal had to be broken by hand and that it was unusually hard and rock-like had a tendency to allow lumps of coal much too large to be charged into the producer. These large lumps, very high in ash, did not burn entirely through; as soon as the burning was well started, a layer of ash formed around the lump, interfering with the combustion of the remaining portion, and before it had time to burn it had passed out with the ashes unconsumed. Because of the general appearance of the coal, but little was expected of it, and the test was started with only partial load. After several hours' run, however, the results warranted full load on the engine.

The following is the result of the test on the West Virginia bone coal:

Proximate Analysis of the Coal.

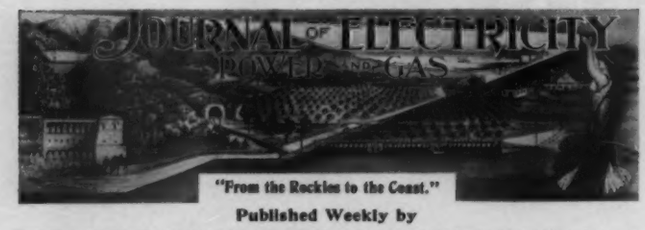
Moisture	0.47
Volatile matter	8.83
Fixed Carbon	46.96
Ash	43.74
	100.00
Sulphur	0.27

Composition of Gas by Volume.

Carbon Dioxide (CO_2)	9.7
Carbon Monoxide (CO)	19.5
Hydrogen (H_2)	16.6
Methane (CH_4)	1.6
Nitrogen (N_2)	52.6
	100.00

Duration of test	50 hours
Coal consumed in producer, as fired, lbs., per hour	378
B. T. U. of coal as fired	8566
Standard gas per lb. of coal consumed in producer cu. ft.	44.1
Efficiency of conversion and cleaning gas	74.1
a B. H. P. developed at engine	228.8
Coal per B. H. P. hr. developed at engine, lbs.	1.65

a Based on an assumed efficiency of 85% for generator and belt.



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REDONDO POWER PLANT.

We publish this week a most complete article descriptive of the Redondo steam-driven electric station of the Pacific Light & Power Company. This station is remarkable in many respects, and perhaps the most noteworthy feature of the entire installation is its exceedingly high every day economy. A careful reading of the description of the plant shows that the high economy of the station is not due to the high efficiency of operation of any one part of the equipment, but is rather the result of the consistent adaptability of every portion of the machinery in size as well as in type to the work to be done.

The purchaser of the plant, the Pacific Light & Power Company, is one of the most successful light and power companies in the country. They have had experience covering years with the operation of water power generating stations, as well as steam driven plants. When it was decided to build a 20,000-horsepower steam plant on the ocean beach at Redondo, the purchasers knew what must be accomplished as regards the economy and reliability of operation of the plant in order to meet the requirements of their business. They knew what their cost of fuel oil would be, and it was but natural for them to insist upon a minimum economy of the complete station, which would conform with the contracts already in force for the sale of electric power, and also be a guide for future contracts.

Again it was not only the economy of the plant as shown by what might be called a laboratory test, but it was necessary for the purchasers to require from the contractors a test which would cover real operating conditions; nor was the reliability of operation eliminated from such tests, and it is a fact which should always be considered, that reliability of operation, or, in other words, the ability to give continuous service, is in many respects as important as high economy in connection with the consumption of fuel.

Under such conditions it was but natural for the purchasers to enter into a contract with Chas. C. Moore & Co., Engineers, for the complete plant. The contractors thereby became responsible to the purchasers for every detail of the station, beginning with the fuel oil and ending with the switchboard, integrating wattmeters. It was of no interest financially to the purchasers as to the efficiency of different parts of the equipment, such as the boilers, engines, generators or auxiliaries, but it was what might be called the financial economy of the plant which was of the greatest importance to them, and by placing the entire contract with a single firm the responsibility for such financial economy was transferred absolutely from the purchasers to the contractors. Further than this, the contractors assumed the responsibility

of operating the plant after its completion, and in fact did operate the plant continuously for a period of about six months, during which time all three units of the plant were in operation and the station delivered to the extensive transmission system of the Pacific Light & Power Company its full normal output of approximately 200,000 kilowatt-hours per day.

It may be interesting to look purely at the financial side of the economy as shown by the test and the economy as guaranteed by the contractors. This point of view is of the greatest interest and really the only point of importance to the stockholders and directors of such a corporation. The financial effect of the plant economy will depend upon the cost of fuel oil delivered in the receiving tanks at the power station. It is immaterial what this cost is, providing we assume some fixed cost per barrel of oil and proportion the cost of fuel and the saving due to high economy, using the actual cost of fuel in any given plant. For convenience we may assume that fuel oil in the tanks at the power station represents to the power company a cost of $1.00 per barrel. With the normal output of the three units of the plant at 200,000 kilowatt-hours per day, if the economy of the plant averages 170 kilowatt-hours per barrel of oil the cost of fuel oil would be approximately $430,000.00 per year. If, on the other hand, the economy of the entire plant, including all auxiliaries for continuous operation under all conditions of load, is 250 kilowatt-hours per barrel of oil, the cost of fuel per annum would be but $246,000.00. This would correspond to a saving in the operation of the plant of $184,000.00 per year.

In the above it is not intended to infer that the cost of the fuel oil for this plant is $1.00 per barrel, but existing conditions on the Pacific Coast are such that this price would not be an excessive cost of fuel oil, except in localities directly adjacent to oil fields. If the cost of fuel oil were one-half of the above assumed value, or $.50 per barrel in the station storage tanks, the cost of fuel oil, if the economy were 170 kilowatt-hours per barrel of oil would be $215,000.00 per annum. If the economy of the station, however, were 250 kilowatt-hours per barrel, the cost of the fuel oil would be but $123,000.00, or a saving of $92,000.00 per year due to the higher economy.

Another point of importance is in connection with the test which was made jointly by the Pacific Light & Power Company and Chas. C. Moore & Co., Engineers, in order to determine the relation between the fuel oil delivered to the burners in the boiler room and the kilowatt-hours net delivered to the switchboard in the operating galleries. This test, which was continuously carried on for fifteen days, did not in any manner or in the least degree interfere with the commercial and continuous operation of the plant. The load carried, and in fact every detail of supervision and attendance, while under the general direction of the committee in charge of the test, was at all times entirely under the control of the regular operators of the station. We believe that it is rare indeed that a test has been made of a large steam plant, the results of which are as reliable as those obtained in this case in which there was so little interference with the regular delivery of energy to the general transmission system, there being connected in this system many other generating stations, both steam and hydraulic.

In conclusion it should be said that the profession is greatly indebted to the Pacific Light & Power Company and Chas. C. Moore & Co., Engineers, for the way in which this plant was designed, installed and tested. By the profession we mean to include engineers, bankers, stockholders and power customers. As a result of the broad policy adopted by the managers of the Pacific Light & Power Company they have one of the best and most economical plants ever built. It is housed in an absolutely fire-proof building, and when it comes to reliability and flexibility of operation it is a question whether any plant ever erected can be said to excel it. There can be no doubt that the tests, which were made of the plant, represented a large expenditure of money on the part of the purchasers, but as is always the case, such broadness of view and painstaking efforts result in the end most advantageously to the company or corporation which is willing to spend their money for such purposes.

On the other hand the contractors were given an entirely free hand and that means that the responsibility for the economy of the plant rested entirely with them. If for any reason the results were not satisfactory no blame could be placed upon the purchasers because restrictions made it impossible for the contractors to carry out their own plans in the installation. The result is that the contractors have the satisfaction of having designed, and built in its entirety, a steam driven electric power plant which will at least be a bench mark for some time to come as regards its economy, utility, reliability and flexibility of operation.

While the present article upon this plant does not give data which shows the efficiency of the different elements of the station, it gives the efficiency of output to input, as shown by the test. It is to be hoped that in the near future additional engineering data may be published, which will be available to determine what maximum economy may be relied upon for the different parts of such a plant, such as the boilers, engines and electrical machinery, each considered as separate machines.

OIL VERSUS COAL AS FUEL.

The Editor.

Sir: My attention has been called to an editorial in "Power and the Engineer" of July 28th, 1908, on "Oil versus Coal As Fuel under Steam Boilers." This editorial justly criticizes my conclusions in an article published in the "Journal of Electricity, Power and Gas," of May 9th, 1908. The term "brake horsepower" is a typographical error, and should have read "boiler horsepower," in accordance with an errata inserted in that jounal of May 16th. A subsequent correction of the figures appeared in the issue of July 25th, 1908. The evaporation given (222.5 pounds of water) per gallon of oil was a mathematical error, and as the rest of the calculations were based on this amount, all were therefore incorrect. However, the editorial in "Power" neglected the fact that the comparison of evaporation in both instances is based from and at 212 degrees F. per pound of dry fuel, and therefore instead of 13.12 the evaporation is 15.34 pounds of water per pound of oil. Furthermore, as the gravity of the oil used was 16.2 degrees Baume, the weight per gallon was 7.98 pounds instead of 7.5 pounds. Consequently we have an evaporation of 122.4 pounds of water per gallon of oil, the cost of this gallon being 2.4 cents. An equivalent evaporation requires 12.96 pounds of coal at a cost of 2.3 cents (assuming the cost of coal to be $4.00 per long ton). This places the fuel value of the oil at 2.3 cents per gallon, or 96 cents per barrel of 42 gallons.

This fuel value corresponds very closely to the average fuel cost of one dollar per barrel. But as the average cost of coal on the Pacific Coast is not $4.00, but $6.00, per long ton, the saving effected is manifest.

Although on the Eastern coast the Standard Oil Company may at present be using coal as fuel, it is a well-known fact that should the price of coal increase, they would revert to the use of oil, as they have done in several instances, both their steamers and plants ashore having used oil and coal alternately, and this in accordance to the fluctuation in price of the latter fuel.

R. F. CHEVALIER.

Alameda, Cal., August 27.

PERSONAL.

S. Howard Rippey, of Sellers & Rippey, consulting engineers at Boston, is at Portland, Oregon.

J. W. Morss, president of the Simplex Electrical Co., of Boston, has been in San Francisco this week.

Arthur O. Einstein, sales manager of the Crescent Company, of Valparaiso, Indiana, is visiting San Francisco.

Peter Murman, of the Decker Electric Company, of San Francisco, is enjoying a vacation in Lake County.

Horace B. Skinner, of Spokane, has been chosen general superintendent of the Okanogan Electric Railway Company.

Jas. T. Anderson has been elected secretary of the Electric, Railway & Manufacturers' Supply Co., 84 Second Street, San Francisco.

Garnett Young, general manager of the Telephone Electric Equipment Company, of San Francisco, has returned from a two weeks' vacation on the Russian River.

Avery P. Eckert, general sales manager of the Duplex Metals Company, of New York, is at the St. Francis, San Francisco, for a few days.

A. B. Merrihew, formerly chief inspector of the Los Angeles Railway in Los Angeles, has been appointed manager of the San Bernardino Valley Traction Co., with headquarters at San Bernardino, California.

Frank J. Quinn, formerly with the Pacific Telephone & Telegraph Company, as purchasing agent, and subsequently with the Western Electric Company, as buyer, has associated himself with the Sterling Electric Company, 133-139 New Montgomery Street, San Francisco, and will act as a director and treasurer of the company.

LOS ANGELES REJUVENATION.

There are now twenty Jovians resident in Los Angeles, eleven having been added to the former number at what was, I think, properly styled a "Joviation and Rejuvenation of the Rejuvenated Sons of Jove," which ceremony was pulled off at the Hotel Virginia, Long Beach, on the evening of August 14th, 1908. The arrangements were largely in the hands of H. Conger Bowers, of F. E. Newberry & Co., Mr. Bowers having a proxy as statesman for the Jovians in Southern California. Mr. Bowers certainly is a success as an arranger.

The party left Los Angeles on a special car at 5 p. m. via Pacific Electric Railway. The following were present: C. E. Winchell, W. R. Green, representing the Johns-Manville Co.; H. V. Carter, C. H. Carter, W. M. Fagan, representing the Pacific Electrical Works; N. W. Graham, R. D. Holabird, representing Holabird-Reynolds Co.; Ira J. Francis, W. G. Stearns, representing John A. Roebling's Sons Co.; C. J. Pyle, representing the Standard Underground Cable Co.; Arthur W. Ballard, H. K. Fish, V. L. Benedict, representing the General Electric Co.; B. F. Kierulff, Jr.; A. L. Havens, representing Pierson-Roeding Co.; Thomas Foulkes, W. B. Woodill, J. E. McDonald, the latter being familiarly addressed as the "Joint Pole Committee." The following ladies were also present: Mrs. Benedict, Mrs. Kierulff, Mrs. Haven, Mrs. Foulkes, Mrs. Woodill, Mrs. McDonald.

Arriving at the Virginia at 6 o'clock, there was some little delay, due to the failure of an electric fountain with which the table was being decorated. It was reported that this failure was due to the blowing of one of Winchell's fuses. During the delay, Mr. H. V. Carter and Arthur W. Ballard entertained the gentlemen in a manner which, owing to the prohibition law of Long Beach, it would be as well not to mention.

The dinner was a great success, so much so that in a burst of enthusiasm Billy Stearns gave the waitress 50 cents. A handsome souvenir was distributed: the figure of Lucifer in red velvet upon a white kid disc with suitable inscription burnt thereon, for which latter a vote of thanks was tendered to Mrs. Bowers.

The rejuvenation ceremonies were held in an enormous basement room, peculiarly well adapted to the purpose, and I believe that at its close the eleven candidates fully realized that they were Jovians. Our genial statesman, Bibbins, was much missed, as were also the "Kink" and the "Prince." Billy Green officiated at the piano both during the initiation and afterwards, and we were also favored with some very classic selections by Mr. Benedict, who is a pianist worthy of remembrance. A few of the party remained at the hotel overnight, but the majority returned on the 11:15 car, greatly pleased with the second meeting of the Rejuvenated Sons of Jove.

TRADE CATALOGUES.

Westinghouse D. C. Motors, Types S and SA, are first described and then illustrated in the many uses to which they have been applied, in Circular No. 1058 from the Westinghouse Electric & Manufacturing Co., Pittsburg, Pa.

Bulletin No. 1107 from the Fort Wayne Electric Works, of Fort Wayne, Indiana, illustrates and describes Standard A. C. Single-Phase Switchboard Panels. The line includes panels equipped for a single generator, for one generator and two circuits, one generator and one transfer circuit, one generator, an incandescent and an arc-lighting circuit, and also feeder panels of different kinds.

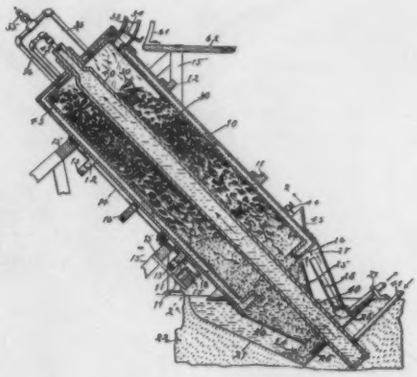
OBITUARY.

W. M. Habirshaw, of the Habirshaw Wire Company, died at Saratoga, N. Y., of apoplexy on August 16.

PATENTS

GAS-PRODUCER. 894,877. Melvin E. Crowell, Franklin, Ind., assignor of one-half to Franklin Fay Chandler, Indianapolis, Ind.

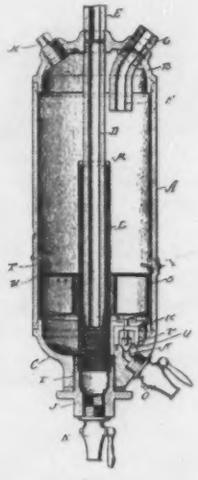
A gas producer including a base with an ash-pit formed therein, a revoluble shell for the coal mounted in an inclined



position with its lower end extending into said ash-pit, and a stirrer projecting centrally through the lower end of said shell into the same, the lower end of said stirrer being embedded and secured in said base.

OIL-FILTER. 895,083. John H. A. Gardiner, Chicago, Ill.

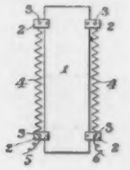
An oil filter comprising a casing provided at its lower end with a threaded opening, a nipple equipped at one end with a petcock, fitting said opening and secured therein, a cylinder of wire cloth and of smaller diameter than said opening secured at its lower end to said nipple, a supply pipe entering said casing, at its opposite end and terminating within



said cylinder, the latter being contracted at its free end to snugly fit said supply pipe, there being an outlet for water in the lower end portion of said casing, a float in the latter of less specific gravity than water and greater specific gravity than oil, and a valve actuated thereby and controlling said outlet, there being an outlet for filtered oil above the lower end portion of said casing.

ELECTRODE FOR THE EVOLUTION OF OZONE FROM OXYGEN OR ATMOSPHERIC AIR. 894,818. John R. Craig, Jr., Glasgow, Scotland.

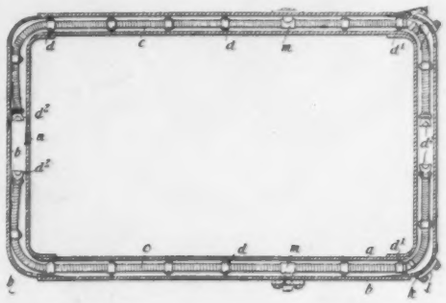
An electrode for the purpose described, comprising a pair



of discharging units for the electric current, a di-electric plate arranged edgewise between said units, and means for detachably securing the units to the plate.

APPARATUS FOR REMOVING SEDIMENT FROM STEAM BOILERS. 895,182. Percy Hulburd, London, England.

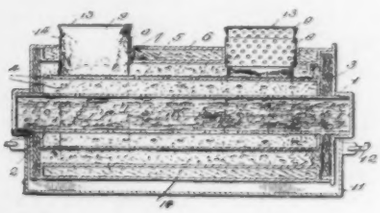
A fire box for steam boilers provided with flexible tubing



between the walls, nozzles provided on said tubing through which sediment may be drawn into the tubing, openings in the outer wall of the fire box to admit said tubing, closures for said openings and means for discharging the sediment from the tubing.

LIQUID-FUEL BURNER. 894,993. John A. Willis, Palmer, Oregon.

In a burner for consuming liquid fuel, the combination of a perforated pipe, a double-walled cylinder fitted upon said pipe and spaced therefrom and having said space supplied with filling material and closed at opposite ends, said cylinder having



corresponding openings in both walls, tubes fitted in the openings of the walls of the said cylinder, and wicks fitted in said tubes and having their inner ends extended into the space between the double-walled cylinder and perforated pipe embedded in the filling material.

INDUSTRIAL

SUCTION GAS PRODUCER POWER.

American Producers for American Coals and Lignites.

By L. P. Tolman.

Development.

Probably no invention has ever come into public favor in so short a time as the suction gas producer. Introduced into the United States about five years ago, this system of developing power from coal and lignite has already become a commercial reality and is fast gaining approval among engineers and power users. The early history of producer gas dates as far back as the year 1509, at about which time the "Fulen Heitzen" first became known, and were described by H. Brunschwyk in his book, "Ars Distillandi de Compositis," or "The Art of Distilling Compounds," which was published in Strasburg, Germany.

The first plant similar to those now in use was built by Mr. Emerson Dowson, who has the distinction of introducing in England, in 1878, the first practical gas producer for power. This was of the "pressure" type. A small steam boiler was necessary, as well as a large gas holder. Mr. Dowson's plants were successful and are still in regular service. Anthracite is the usual fuel.

The next substantial progressive step was taken when Dr. Ludwig Mond, in England, in 1889, developed the first successful soft-coal producer. This became a standard for sizes of 250 horsepower and larger, but proved too elaborate and expensive for use in smaller sizes. With this plant a large gas holder is needed, also a steam boiler and an elaborate system of gas washers, purifiers, and economizers.

Then followed the invention of Herr C. Wiegand, of Hanover, Germany, who in 1895 took out the first patent (No. 88,044, German) on the principle of the modern suction gas producer. The importance of this invention was not realized in Germany until some years later.

In France, during the same year, Benier built what is believed to be the first practical suction gas producer. This was a success as soon as the necessary changes had been made in the gas engine to adapt it to the "suction" system. It is surprising in this case, as with most other great inventions now in general use, that an apparatus so simple and easily understood was not developed long before.

About five years ago American manufacturers began to take a live interest in the success of European, and especially German, suction gas power plants. American engineers visited Europe and in this way learned at first hand what was being done abroad. As early as the year 1904, it is estimated that there were over 10,000 suction gas power plants in Germany alone. They had come into general use and were found in the finest hotels, stores, factories, etc., for electric lighting and other power purposes. The actual users of the plants were enthusiastic over the results.

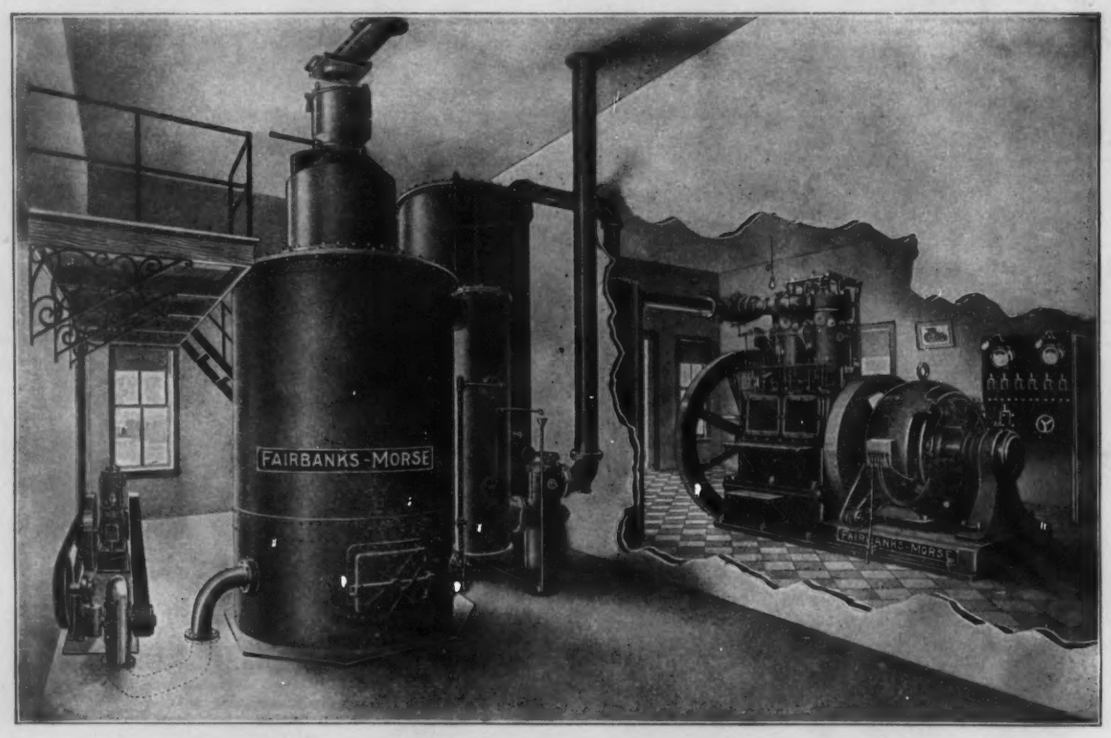


Fig. 1. A Complete Producer Gas Power Plant with Engine Direct Connected to Electric Generator.

That producer gas power is a pronounced success in the United States is evidenced by the large number of satisfactory installations already in operation on American coals. It is estimated that there are over 500 producer power plants in this country, having an aggregate of 150,000 horsepower. Of these, about eighty-five per cent are of the "suction" type and fifteen per cent of the "pressure" type. The suction plants average approximately 100 horsepower each, while pressure plants are usually built in sizes larger than 1,000 horsepower.

This article deals with suction gas power plants in single units of 200 horsepower, or smaller, and complete plants made up of a number of such units 1,000 horsepower, or larger. This range of sizes covers the requirements of the great majority of power users.

Comparative Waste with Steam and Producer Gas Power.

This idea is illustrated graphically. Fig. 2 illustrates a modern steam plant with its many complications, including compound condensing steam engine with water-tube boiler.

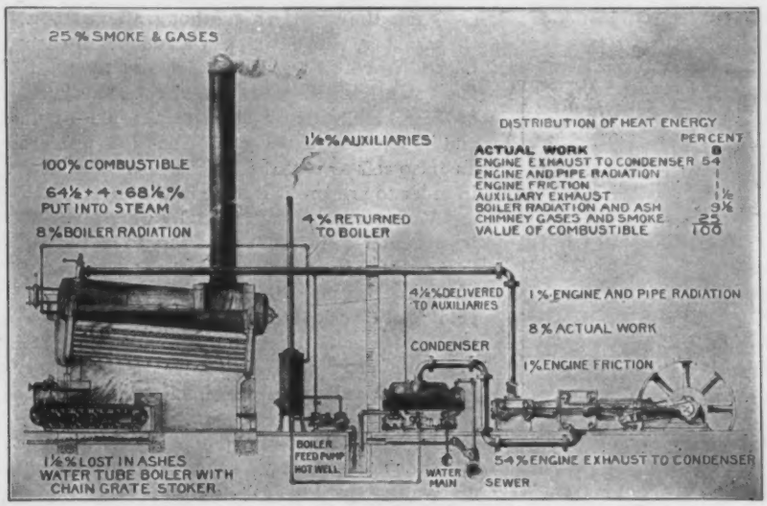


Fig. 2. Compound Condensing Steam Plant.

This plant converts 8 per cent of the total energy of the fuel into useful work. (In actual practice the percentage utilized is usually less.) In other words, 92 per cent or more of the energy in the coal goes to waste as smoke up the chimney, exhaust from the engine, heat radiation, etc.

A 150-horsepower steam plant of this type, running at two-thirds load, 3,100 hours per year, uses approximately 4½ pounds of coal per brake horsepower per hour. With coal at $2.75 per ton, the fuel alone costs $1,918.12 per year. In addition, it requires the entire time of at least one man to operate the plant. The boiler, especially, requires constant care, cleaning and repairs, and is always a source of danger.

Fig. 4 illustrates a suction gas producer power plant. The apparatus is simple, reliable, and amazingly economical. With this plant 18 per cent of the total energy of the fuel is converted into useful work. (Varies according to conditions from 15 to 21½ per cent.) This means that a suction gas producer plant uses from one-half to one-fourth as much coal for a given amouni of power as a steam plant.

A 150-horsepower suction producer plant, running two-thirds load, 3,100 hours per year, uses approximately 1½ pounds of coal per brake horsepower per hour. (Tests have been made showing a consumption of less than 1¼ pounds at two-thirds load and less than one pound at full load.) With anthracite at $5.00 per ton, the fuel alone costs $1,162.50 per year. Furthermore, the cost of attendance can be reduced materially with a producer plant, as the operator can spend part of his time in other useful work.

Fig. 3 illustrates the ordinary throttling governor steam engine with tubular boiler, a type which is in very general use, especially in sizes from 15 to 200 horsepower. This plant converts 5 per cent (though usually much less) of the total energy of the fuel into useful work. In small steam plants the total amount of energy utilized is often not over two or three per cent. In other words, 95 per cent or more of the energy in the coal goes to waste as smoke up the chimney, exhaust from the engine, heat radiation, etc.

A 150-horsepower steam plant of this type, running at two-thirds load, 3,100 hours per year, uses approximately 7 pounds of coal per brake horsepower per hour. With coal at $2.75 per ton, the fuel alone costs $2,983.75 per year. In addition, it requires the entire time of at least one man to operate the plant. The boiler, especially, requires constant care, cleaning and repairs, and is always a source of danger.

Government Tests.

Much valuable information is given in the report of the United States Geological Survey concerning the fuel-testing plant at the Louisiana Purchace Exposition, St. Louis, Mo. For three years the government experts conducted a series of tests on many samples of coal from mines all over the country. Briefly, the apparatus included a non-condensing Corliss engine steam plant with water tube boiler and a pressure type producer with three-cylinder vertical gas engine.

From the summary of results obtained from a long series of tests, the fuel consumption in pressure type producer plant varied from 1.18 to 3.47 pounds per brake horsepower per hour, the average being approximately 1¾ pounds. The average with the Corliss steam plant was found to be approximately 4½ pounds, using similar fuels. With lignite, the consumption in pressure producer plant was from 1.95 to 3.47 pounds, the average of five samples actually figuring 2.60 pounds. With Corliss steam plant using lignite, the average consumption of "coal as fired" (not "dry coal") was approximately 7 pounds.

While most of the above tests were on bituminous coal, which cannot be used advantageously in a suction producer, yet the consumption of anthracite in the latter is usually less than as stated for bituminous coal in "pressure" type producer, probably due to the fact that there is less resistance to the flow of gas in the suction type. For example, tests on lignite in a suction producer commonly show a consumption of 2 to 2¼ pounds, whereas from the five lignite tests

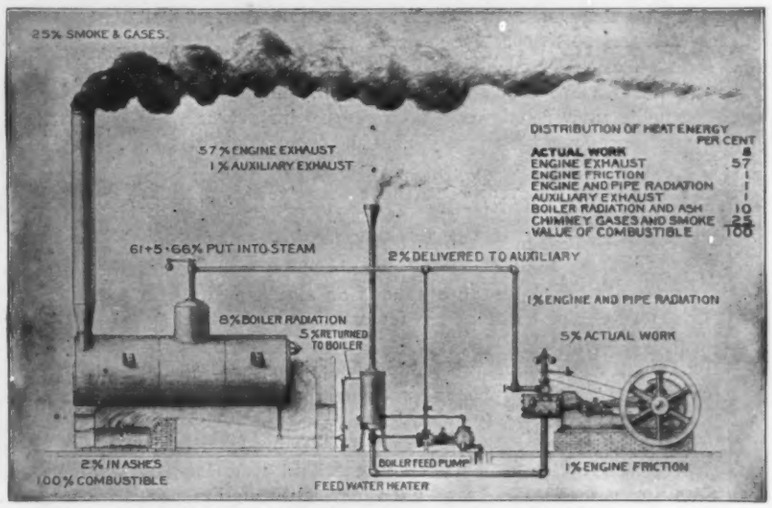


Fig. 3. Simple Steam Engine and Tubular Boiler.

at St. Louis the average is 2.60 pounds in a pressure producer plant.

Advantages of Suction Gas Producer Power.

We have already discussed the high thermal efficiency of the suction gas producer plant. The most important and the most practical commercial advantage is the economy effected in the cost of developing power. If there were no other advantages, this one feature would be sufficient reason for installing this system. Other advantages may be summed up briefly:

Simplicity. The producer, in which fuel gas is generated from coal, is almost as simple as an ordinary furnace for heating purposes. The gas engine is entirely automatic in operation and needs little more than the ordinary cleaning and care as to lubrication.

Absolute safety. There is no danger from explosion or from fire. It is absolutely safe, even in the hands of men with little mechanical training, and the many plants which are in continuous operation, some of them twenty and even

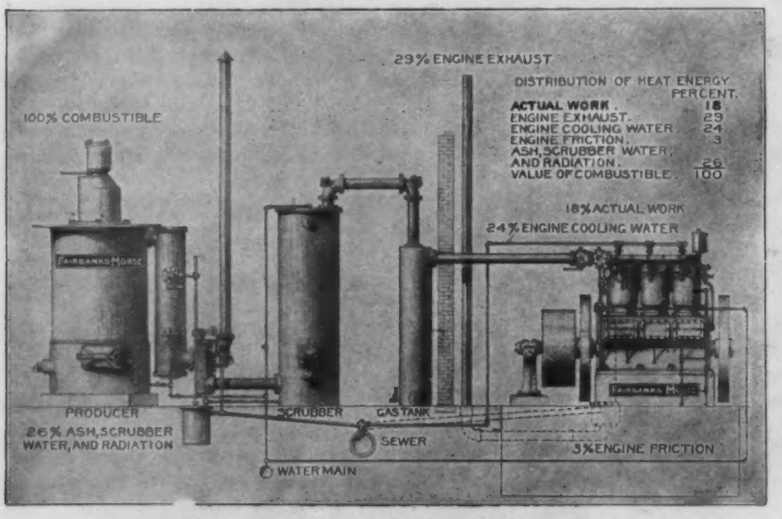


Fig. 4. Suction Gas Producer Power Plant.

twenty-four hours a day, indicate that they are thoroughly reliable and will stand hard, every-day usage. Boiler insurance is unnecessary with producer plants and the troubles and dangers encountered with steam boilers are entirely avoided. The complete gas engine and suction producer plant is almost entirely automatic in operation, very little attention being required. Ordinarily the operator only needs to spend ten to fifteen minutes about every two hours to dump a few buckets of coal into the producer and give general attention to the plant. He can spend part of his time in other useful work, and an extra man as fireman is not required, even with plants of from 400 to 500 horsepower.

No smokestacks and no smoke. Hundreds of thousands of dollars which are now spent annually in building smokestacks can be saved; and what is of greater importance, the smoke nuisance can be entirely abated. The value of this feature can hardly be overestimated, and such an ideal condition seems almost incredible to those who are not familiar with the subject.

Less coal to be handled and stored. Where the suction gas producer plant uses 1¼ or 1½ pounds of coal, the steam plant commonly requires 4 to 6 pounds or more. Moreover, with the producer plant there are fewer ashes to be handled and disposed of.

Starting. The producer will hold fire all night, or even for several days, and the proper quality of gas can be generated after fifteen or twenty minutes' blowing to revive the fire. The engine can easily be started on compressed air, and after getting up to speed is then operated on producer gas.

Stand-over loss. The stand-over loss with suction producer amounts to about one-third as much as with a steam boiler. In other words, where the stand-over loss with a steam plant for fourteen hours amounts to 600 to 800 pounds, or more, with a suction producer plant of the same horsepower this loss would not exceed 200 pounds.

Suction Gas Producers.

Fig. 5 illustrates an exterior view and Fig. 6 a sectional view of a Fairbanks-Morse anthracite suction gas producer. All of the principal features are clearly shown. Coal is admitted to the producer through a hopper at the top. This has double closure, so that fuel can be introduced without at the same time admitting air. In the process of partial combustion which takes place, producer gas is generated.

The hot gas passes through a vaporizer in which a small amount of steam is formed, which, with a limited amount of air, passes under the grate of the producer. In the smaller sizes, the vaporizer is at the top of the producer, where it uses the waste heat from the escaping gas and where, at the same time, the water keeps the top from getting too hot. In the larger sizes the vaporizer is separate and connected to the producer by piping.

From the vaporizer, the hot gas flows through the scrubber, which is merely a cylindrical-shaped tank filled with coke, over which a spray of water is constantly sprinkled. The large contact surface of the coke effectually cleanses the gas of dust and impurities carried over from the producer, and also acts to cool the gas, which is essential in order to prepare it for use in the engine.

With certain fuels, especially when much tar is encountered, it is also necessary to add a sawdust purifier in order to abstract the last traces of tar from the gas. While not absolutely essential, yet it is always advisable to use a gas tank between the scrubber and the engine, in which a certain amount of gas is stored in ready use for the engine. This is especially desirable where the loads are variable.

In the care of the producer, the principal attention needed is to poke the fire every few hours, according to quality of the coal, in order to break up and remove clinkers, which would otherwise interfere with the making of sufficient gas. Poke holes are provided so that every part of the fire can be reached conveniently.

Fuels.

Anthracite in "buckwheat" or "pea" sizes, liginite, coke, and charcoal are the fuels commonly used. In many sections these small sizes of anthracite can be bought cheaply in car lots. For example, in Chicago the carload price of "buckwheat" anthracite is usually about $3.75 per ton. In some of the States west of Chicago the price varies from $5.00 to

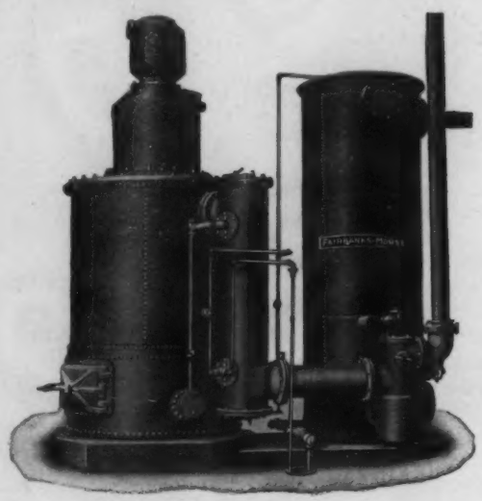


Fig. 5. Fairbanks-Morse Suction Gas Producer.

$7.00 per ton. At some points in southern Canada these small sizes of Pennsylvania anthracite can be bought for from $3.00 to $4.00 per ton. In some of the Eastern States, which are nearer the source of supply, the prices are even less.

The lignite producer offers a wonderfully cheap and reliable power in sections where this fuel is available. There are enormous deposits of lignite in Texas, Arkansas, Louisiana, North Dakota, Montana, Wyoming, Colorado, and other Western States. This can usually be had at a price of from

$1.00 to $3.00 per ton. At Smithville, Texas, where a 150-horsepower lignite producer plant is installed, the cost is $1.70 per ton. Lignite is of little value for steaming purposes, mostly due to the large amount of moisture, but it makes a most excellent fuel for the producer and in some respects is easier to handle than anthracite. Coke and charcoal are economical fuels in some sections and can be used separately or mixed with anthracite.

In order to give some idea of the relative value of different producer fuels, the results of tests on a number of samples are given. These samples were received from various parts of the United States, as well as from foreign countries. For example, in Table 1, giving the analyses of different anthracites, sample 65 is from Europe, 101 and 76 from Pennsylvania, 71 from Elk Mountain, Colo., and 89 from Banff, B. C., Canada. The following tests were made by the experimental department at the works of Fairbanks, Morse & Co., Beloit, Wisconsin:

Table 1—Anthracite.

Sample No.	B.T.U. per lb.	Fixed Carbon	Volatile	Ash	Moisture	Sulphur	Quality
65	15,434	88.8	7.4	2.9	.9	.99	Very Good
101	13,952	83.5	5.5	8.2	2.8	.82	Good
76	12,058	73.9	5.7	18.9	1.5	.86	Poor
71	13,332	77.2	9.3	13.4	.1	.73	Fair
89	14,746	79.3	8.1	10.5	2.1	.59	Good

With the best coal there is little formation of clinker that will not work down to the grate without poking from the top, and many European producers have no top poke holes. These are not successful on American coals, for while it is always desirable to get the best coal, it is practical to operate continuously on an average, or even a poor coal, by working the clinkers down through top poke holes. It is an advantage in using poor anthracite to have large producers.

Table 2—Coke.

Sample No.	B.T.U. per lb.	Fixed Carbon	Volatile	Ash	Moisture	Sulphur	Quality
73	12,787	86.7	2.4	8.4	2.5	.93	Good
77	14,213	92.3	1.7	5.8	.2	.6	Very Good
94	9,528	79.4	3.7	14.3	2.6	.59	Rather Poor
97	13,811	90.4	1.7	6.1	1.8	.55	Very Good

This fuel varies in quality according to the soft coal used in its manufacture and the method of treatment. All coke must be crushed to pass a screen of 1-inch or 1¼-inch mesh, and must be freed from dust with a fine screen. It is usually advisable, where coke is used, to install one size larger producer than standard. A sawdust purifier is also desirable to remove dust, which is more abundant than with anthracite.

Gas from coke averages about 115 British Thermal Units per cubic foot (lower heating value), while from anthracite it averages 125 or more. For this reason the power capacity of the engine will be a little less on coke gas, but not as much less in proportion as the heating value. Some coke will not maintain the fire hot enough. Mixing one part anthracite with two of coke usually corrects this.

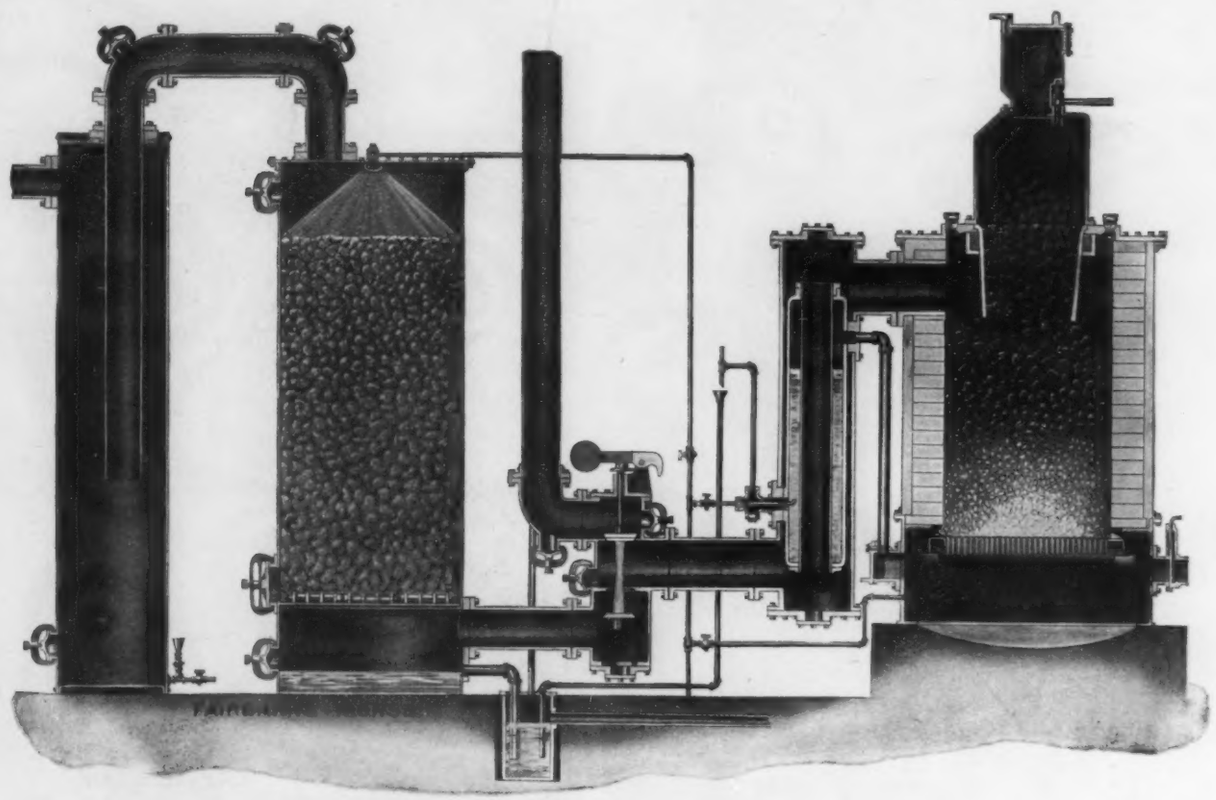


Fig. 6. Sectional View of Fairbanks-Morse Suction Gas Producer.

Charcoal.

British Thermal Units, per pound, 14,438; Fixed Carbon, 81.3; Volatile, 12.9; Ash, 1.1.

The use of this fuel becomes practical by the addition of a centrifugal tar extractor located between the scrubber and a sawdust purifier. With this fuel, also, it is advisable to install one size larger producer than with anthracite.

Charcoal gas has a heating value averaging 130 British Thermal Units or more, and because of this gives somewhat more power at the engine. It can be used in as large pieces as will readily go through the producer charging hopper. Less tar results from charcoal that is perfectly charred, but more or less material not perfectly charred is likely to be found. No clinkers are formed with this fuel.

Table 3—Lignite.

Sample No.	B.T.U. per. lb.	Fixed Carbon	Volatile	Ash	Moisture	Sulphur
51	11,634	20.3	46.1	6.3	27.3	1.01
57	8,753	29.4	35.7	7.1	27.8	.63
95	11,566	41.8	36.7	3.7	17.8	.41
103	9,765	36.8	35.8	10.7	17.2	4.09

Lignite cannot be used in standard anthracite producers, but the Fairbanks-Morse lignite producer operates very successfully with this fuel. Gas from lignite averages 130 British Thermal Units per cubic foot. This fuel can be fed to producer in any size that will go through the charging hopper, and it causes no serious trouble from clinkers.

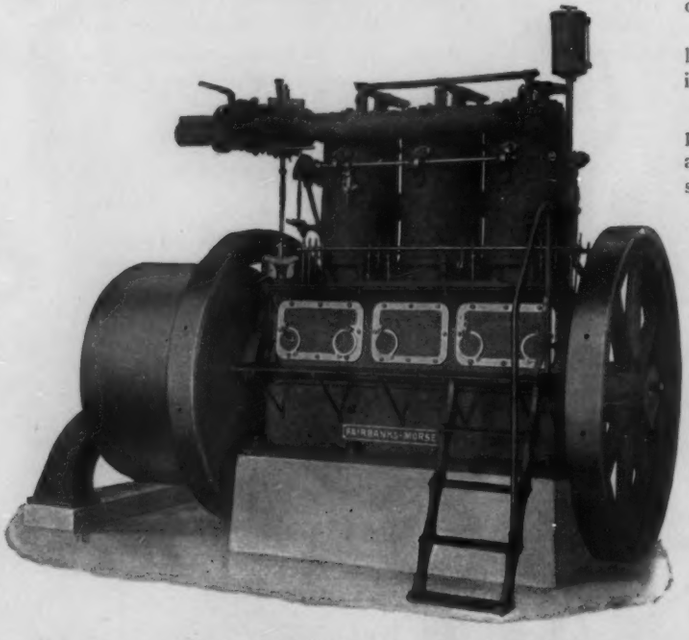


Fig. 7. Multi-Cylinder Vertical Producer Gas Engine.

Producer Gas Engines—Vertical Type.

These engines are made in sizes of 200 horsepower and smaller. By combining several units, plants of 800 to 1,000 horsepower or larger have been installed. Fig. 7 illustrates a thoroughly modern Fairbanks-Morse engine of this type. Sectional view is shown in Fig. 8. It may be of interest to engineers to note briefly a few of the carefully developed features in the design of these engines.

The present system of ignition is a great improvement over the methods formerly used. The make-and-break igniter is so constructed that it can be adjusted to spark as early or as late as desired, when engine is running or at rest, by means of a convenient hand lever. A single lever controls the time of ignition for all cylinders. This is a feature of much importance, especially with producer gas, as it permits timing the ignition to give the greatest possible power and economy with any particular grade of gas and when the engine is running. In addition, there is an independent adjustment for each igniter, which is operated by drop cam.

Igniters can be removed, inspected, and cleaned, without interfering with other working parts, and they are located most conveniently. As the successful operation of a gas engine depends largely upon the igniter, the value of these features cannot be emphasized too strongly.

Both valves are mechanically operated from a single cam shaft, which is located inside the crank case. This minimizes the amount of noise, and furthermore the two-to-one reduction of gearing includes pinion, which is made of alternate layers of steel and red fiber. These features insure a quiet-running engine.

The simple fly-ball governor is of a most carefully designed pattern. This operates a balanced disk valve, which is so constructed that there is no frictional contact or surface to become fouled by any impurities in the gas. This is especially important with engines operating on producer gas. The governor insures very close regulation, adapting the engine for electric lighting and other service requiring uniform movement.

Lubrication is effected by means of a single elevated oil reservoir, which is provided with separate brass pipe with individual sight feed for each bearing. This is a most effective system of engine lubrication and has been adopted as the best to be had. The drip from the different bearings collects in the base of the engine, which is drained by means of a small pump. The oil is run through a filter and is then

Each engine is fitted with a hand-operated speed regulator, by means of which speed can be reduced when engine is running.

One cylinder of each engine is fitted with automatic compressed air starting gear. This can be thrown into or out of action by the movement of a single lever, and the engine is started automatically on compressed air.

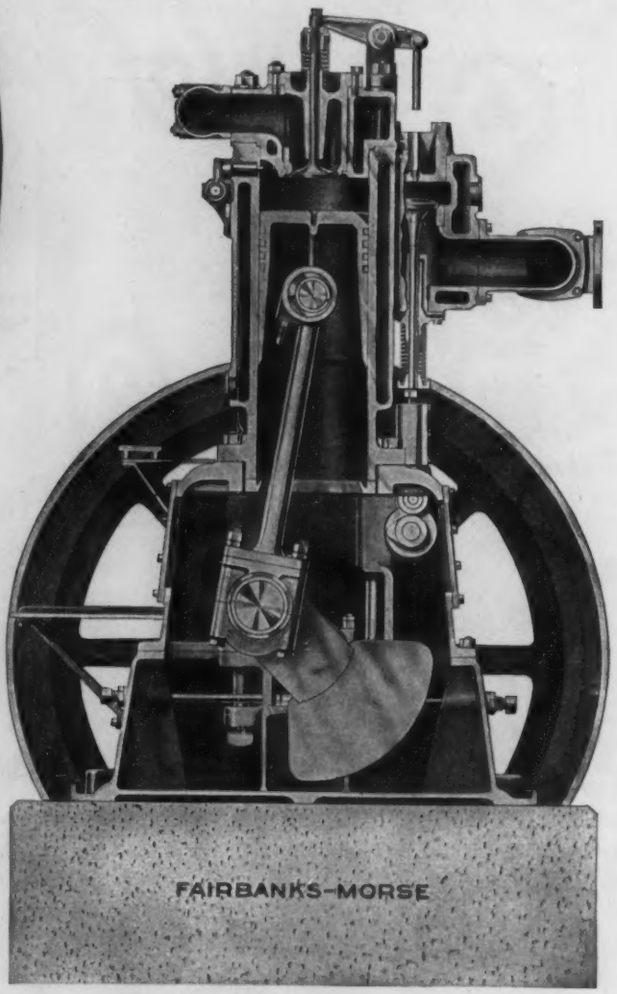


Fig. 8. Sectional View of Engine Showing Principal Working Parts.

Producer Plants in Actual Service.

A very unique producer installation is illustrated in Fig. 9, which shows a large dredge in use at the present time in the State of Iowa. A 150-horsepower Fairbanks-Morse producer plant is installed on this dredge, some of the machinery of which is electrically operated, and the engine also furnishes power for electric lighting.

This plant operates twenty-four hours a day and is handled by two men, one for each twelve-hour shift. While it

has been subjected to the hardest kind of usage, yet this plant has been entirely satisfactory in every particular.

From report on 50-horsepower plant used in operating marble works in Tennessee, statement is made that they use only eighteen ordinary hods of buckwheat anthracite per day of nine hours at a total cost of $1.39 for the coal. At this plant they poke the fire once in the morning before starting, and once at night after shutting down. Outside of this the plant requires very little attention. The following is taken from letter written by the president of the company:

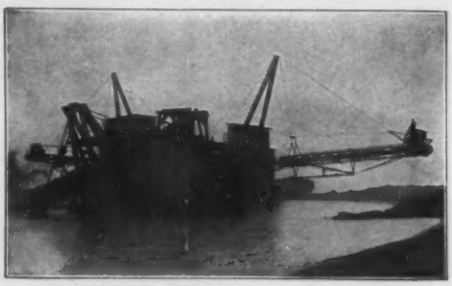


Fig. 9. Dredge Operated by 150 H. P. Producer Plant.

"We are more than pleased with the outfit, from the fact that it has proven entirely satisfactory, and in our minds is the cheapest power that can be installed. We take pleasure in recommending it to any and all manufacturers who are in the market for power, because of its durability and economy, with service unsurpassed."

At one 150-horsepower installation in Western Iowa, actual figures show that cost of coal and oil is $105.90 per month. With their former Corliss engine steam plant, and with somewhat smaller load the cost of coal and oil amounted to $366.60 per month.

A most remarkable showing has been made at a point in Texas, where the city electric light and water works plant is now being operated by a 150-horsepower Fairbanks-Morse producer gas engine, using Texas lignite as fuel. In the words of the proprietor:

"A careful figuring of the former fuel and labor conditions, as compared with the present conditions, demonstrates that we are saving in operating expenses $900.00 per month."

A steam plant was formerly operated at this point, using crude oil as fuel. They were unable to burn enough lignite under the boilers to keep up steam and to do the required work.

One of the largest suction gas producer plants in the United States is illustrated in Fig. 10. This plant comprises six 150-horsepower engines and one 200-horsepower engine—1,100 horsepower in all—complete with suction gas producers, using anthracite as fuel. This plant is in Wisconsin, and is operated twenty to twenty-four hours each day, excepting Sundays and holidays.

There was previously in use in these works a Corliss steam plant, run non-condensing, with water-tube boilers, using Illinois soft coal as fuel. While it is difficult to make accurate comparisons as regards fuel consumption, yet, as a matter of general interest, it may be stated that the steam plant required approximately three and two-thirds times as much coal per unit of power developed as the present producer gas power plant.

Fuel Consumption and General Comments.

A series of tests have recently been made on a 150-horsepower Fairbanks-Morse engine and anthracite producer, for continuous runs of twenty-four hours, at ¼-load, ½-load, ¾-load, and full load, the object being to determine the comparative economy at different loads.

The coal used was an ordinary grade of buckwheat Pennsylvania anthracite, running rather high in ash, the analysis being as follows:

Fixed Carbon	78.9%	Moisture	2.7%
Volatile	5.3%	Sulphur	0.77%
Ash	13.0%	B.T.U. per lb. as fired	13,590

Some of the results of these tests, including the coal consumption per brake horsepower hour, are given below:

Load	B.H.P. on Engine	Speed R.P.M.	Coal in 24 Hours	Coal per B.H.P. per Hour	Cooling Water per B.P.H. Hour, Gals.	Steam per lb. of Coal, lbs.
Full	149.4	224	3838	1.07	5.0	0.48
¾	113.1	226	3185	1.13	5.6	0.45
½	75.4	226	2369	1.30	6.8	0.41
¼	38.0	228	1590	1.74	13.1	0.35

Economy tests have often shown a lower consumption than indicated above—frequently less than one pound of coal per brake horsepower hour at approximately full load. The figures are of value as giving the comparative fuel consumption at different loads, and for this purpose they may be considered as conservative and accurate.

The remarkable economy, together with the numerous other advantages mentioned briefly in the foregoing, have created a large and steadily-growing demand for this form of power equipment. This fact and the surprisingly large number of installations already in successful operation on American coals, indicate that a new industry has been created in this country.

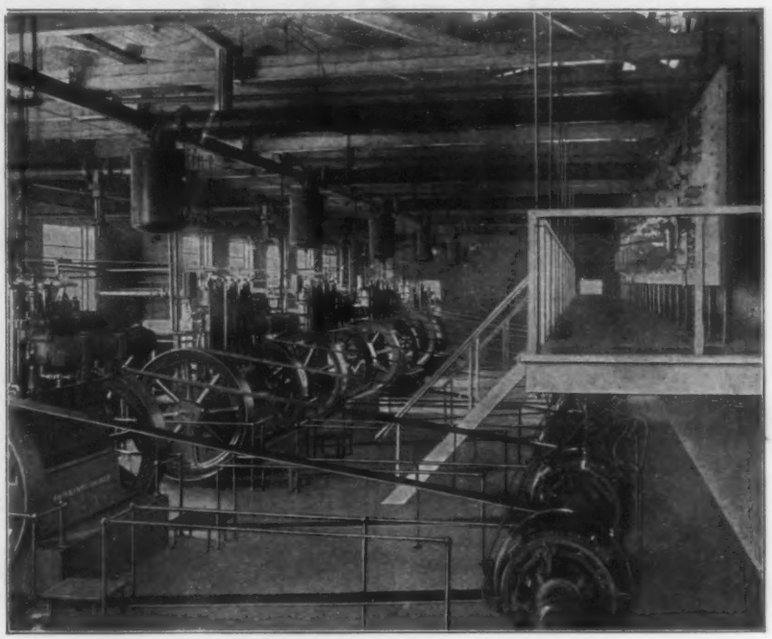


Fig. 10. A 1100-H. P. Suction Gas Producer Power Plant.

Power users and engineers will welcome suction gas producer power as the logical solution of many of their power problems, especially in sections where local fuel costs are favorable. Indeed, when the actual merits of the subject are considered, it is not unreasonable to predict that the demand for producer gas installations may soon exceed even the most optimistic hopes of the manufacturers.

APPROVED ELECTRICAL DEVICES.

LAMP GUARDS.

"Never-Break" Guards, for pendant lamps only. Cat. Nos. 63, 65, 67, 71, 73, 102-107 inclusive, 109, 111, 113, 115, 117, 150, 152, 154, 156, 205, 210, 215, 225, 230, 235. For attachments to sockets: Cat. 1-8, incl., 5A, 6A, 7A, 8A; 13-19 incl.., 42, 100, 140-143 incl.; 161-168 incl., 170, 172, 174, 176, 200, 202, 204, 206, 240-247 incl. Portable handles and guards: Cat. Nos. 70, 72, 74, 76, 78, 80. Ceiling Guards: Cat. Nos. 50, 52, 54, 56. Cluster and arch globe guards and globe nets. Approved July 6, 1908. Manufactured by

Hamblin-Russell Mfg. Co., Worcester, Mass.

CONDUIT OUTLET BUSHINGS AND COUPLINGS.

T. & B. galvanized iron outlet bushing for rigid conduit, also T. & B. hood connector, a coupling for securing flexible steel construction and armored cable at outlets. Approved July 5, 1908. Manufactured by

Thomas & Betts Mfg. Co., 299 Broadway, New York.

CONDUIT OUTLET PLATES.

"Fancleve," Cat. Nos. 601 to 605 inclusive, for knob and tube work. "Fancleve," Cat. Nos. 700 to 701 inclusive, for flexible armored cable. "Fancleve," Cat. Nos. 171 to 175 inclusive, and Nos. 161 to 165 inclusive, for use with canopies of fixtures where supply wires are in wooden moulding. Approved July 5, 1908. Manufactured by

John L. Gleason, Jamaica Plain, Mass.

FLEXIBLE CORD, PENDANT.

Tag on coil to read "Nat'l Electric Code Standard" Marking. Yellow cotton thread cabled with copper strand Approved July 2, 1908. Manufactured by

American Electrical Works, Providence, R. I.

Tag on coil to read "Nat'l Code Standard" Marking. Soft woolen thread on rubber surface lengthwise of wire and under braid. Approved July 2, 1908. Manufactured by

American Steel & Wire Co., Worcester, Mass.

Tag on coil to read "Nat'l Electric Code Standard" Marking. Red, white and blue cotton thread cabled with copper strands. Approved July 2, 1908. Manufactured by

Crescent Ins. Wire & Cable Co., Trenton, N. J., for Alfred F. Moore, Philadelphia.

Tag on coil to read "Nat'l Electric Code Standard" Marking. Green threads in cotton wired around copper strands. Approved July 2, 1908. Manufactured by

General Electric Co., Schenectady, N. Y.

Tag on coil to read "Nat'l Electric Code Standard" Marking. One red and two green threads parallel with the conductor and between the rubber insulator and the braid. Approved July 2, 1908. Manufactured by

Goodyear Rubber Insulating Co., 105 E. 131 St., New York.

Tag on coil to read "Nat'l Electric Code Standard" Marking. Two blue cotton threads cabled with copper strands. Approved July 2, 1908. Manufactured by

National India Rubber Co., Bristol, R. I.

Tag on coil to read "Nat'l Electric Code Standard" Marking. One red thread cabled with copper strands. Approved July 2, 1908. Manufactured by

John A. Roeblings, Trenton, N. J.

Tag on coil to read "Nat'l Electric Code Standard" Marking. Yellow thread in cotton wound around copper strand. Approved July 2, 1908. Manufactured by

Safety Insulated Wire & Cable Co., 144 Liberty St., New York, N. Y.

Tag on coil to read "Nat'l Electric Code Standard" Marking. Brown thread cabled with copper strand. Approved July 2, 1908. Manufactured by

Standard Underground Cable Co., Pittsburg, Pa.

ARMORED CORD FITTINGS.

Catalogue Nos. 5302-03-04, for use with approved rosettes and sockets and at terminals. Cat. No. 6115, for pendant use with standard sockets or switches having cap threaded for ⅛-inch pipe. Approved July 5, 1908. Manufactured by

Sprague Electric Co., 577 W. 35th St., New York, N. Y.

MISCELLANEOUS.

Electrically operated sorting and tabulating machine relay, energized from lighting circuit, driven by 1-10-horse-power motors, 125 or 250 volts, D. C. Dept. June, 1908. Suitable safeguard for the uses proposed when connections to supply circuit are made as specified in the National Electric Code. Approved July 5, 1908. Manufactured by

Tabulating Machine Co., 1054 31st St., Washington, D. C.

ARMORED CORD FITTINGS.

"Electrolet" Fixture Hanger. A two-piece, cast-iron device for chandelier and bracket fixtures. Approved July 5, 1908. Manufactured by

Watt & Raymond, Philadelphia, Pa.

PANELBOARDS.

Two and three-wire panelboards for 125, 250-volt branch circuits, equipped with terminals for open link or cartridge enclosed fuses. Approved July 5, 1908. Manufactured by

Leonard Bundy Electric Co., Cleveland, Ohio.

RECEPTACLES, FOR ATTACHMENT PLUGS.

Kliegl Stage Pocket and Receptacle, Single and Gang Types. Cat. Nos. 216 to 219 inclusive, with red fiber or boxwood plug. Cat. No. 301, with clamp for removing the strain of cable from terminals, 50 A., 125 V. Approved June 8, 1908. Manufactured by

Universal Electric Stage Lighting Co., 1393 Broadway, New York.

RECEPTACLES, STANDARD.

"Bryant" brass shell wall sockets, key (50 C. P., 250 V.) and keyless (3 A., 250 V.), straight and angle base types, Cat. Nos. 9,184, 9,185, 50,717, slotted or closed base types and 50,753 and 50,755. Wall Sockets mounted on K W link fuse, rosette base, 2 A., 125 V., cleat and concealed types. Cat. Nos. 50,729, 50,730, 50,732 and 59,733. Also above types with shade holders attached. Approved June 10, 1908. Manufactured by

The Bryant Electric Co., Bridgeport, Conn.

RECEPTACLES, STANDARD.

Weber Wall Sockets, Cat. Nos. 61,672-61,677 inclusive. Bases either solid or slotted. Cleat, concealed and angle base types, 3 A., 250 V. Approved May 29, 1908. Manufactured by

Weber Electric Co., Schenectady, N. Y.

SWITCHES, SURFACE SNAP, SUB-BASE FOR.

A pressed steel base for mounting surface snap switches on lath and plaster walls, or knob and tube work. Approved May 20, 1908. Manufactured by

De France & Streib, 16 Produce Exchange, Toledo, Ohio.

RECEPTACLES, WEATHERPROOF.

"Paiste" Weatherproof Receptacles, Cat. No. 9,408, 3 A., 250 V., with bottom wires. Cat. No. 9,407, 3 A., 250 V., with side wires entering one inch from bottom surface of receptacle. Approved June 22, 1908. Manufactured by

H. T. Paiste Co., 32d and Arch Sts., Philadelphia, Pa.

SOCKETS, WEATHERPROOF.

"Cole" composition sockets, pendant style, Cat. Nos. 60,666 and 43,310, made in black or brown finish. Approved June 24, 1908. Manufactured by

Henry Cole & Co., 170 Purchase St., Boston, Mass.

SWITCHES, AUTOMATIC.

"Brauer" Automatic Time Switch, 50 A., 250 V. A double-pole knife switch mounted in a heavy iron case. The operation of the switch governed by a double spring and alarm clock attachment. Approved June 22, 1908. Manufactured by

R. B. Brauer, 209 W. Broad St., Richmond, Va.